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The Status of Endangered Whales

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On the cover: Humpback whales feeding off Southeast Alaska. Photograph by L. Gerber.

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The Great Whales: History and Status of Six Species Listed as Endangered Under the U.S. Endangered Species Act of 1973

Simona L. Perry, Douglas P. DeMaster, and *Gregory K. Silber*

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The Great Whales: History and Status of Six Species Listed as Endangered Under the U.S. Endangered Species Act of 1973

A Special Issue of
the *Marine Fisheries Review*

SIMONA L. PERRY, DOUGLAS P. DeMASTER, and GREGORY K. SILBER

The Status of Endangered Whales: An Overview

Introduction and Background

In the history of whaling from prehistoric to modern times, the large whales, sometimes called the "great whales," were hunted most heavily owing in part to their corresponding value in oil, meat, and baleen. Regional populations of North Atlantic right whales, *Eubalaena glacialis glacialis*, were already decimated by 1700, and the North Atlantic gray whale, *Eschrichtius robustus*, was hunted to extinction by the early 1700's (Mitchell and Mead[1]).

Then, as whalers turned to modern, mechanized forms of whaling in the 1860's, worldwide populations of gray; bowhead, *Balaena mysticetus*; humpback, *Megaptera novaeangliae*; blue, *Balaenoptera musculus*; fin, *Balaenoptera physalus*; sei, *Balaenoptera borealis*; and sperm, *Physeter macrocephalus*, whales were in some instances greatly reduced (Tønnessen and Johnsen, 1982). However, as their numbers have diminished, concern for their (and other species) well-being has increased, and has resulted in such U.S. laws as the Endangered Species Conservation Act (ESCA) of 1969, the Marine Mammal Protection Act (MMPA) of 1972, and the Endangered Species Act (ESA) of 1973. Under these laws, eight species of large whales have been added to the List of Endangered and Threatened Wildlife (the List). Smaller species of whales (e.g. minke whale, *Balaenoptera acutorostrata*), whose numbers have remained fairly constant, have not been listed as endangered.

This report reviews the history and status of six species of endangered whales: right, humpback, blue, fin, sei, and sperm whale (Fig. 1). The other two

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[1] Mitchell, E. D., and J. G. Mead. 1977. History of the gray whale in the Atlantic Ocean (Abstr.). *In* Proceedings of the second conference on the biology of marine mammals, San Diego, Calif., p. 12.

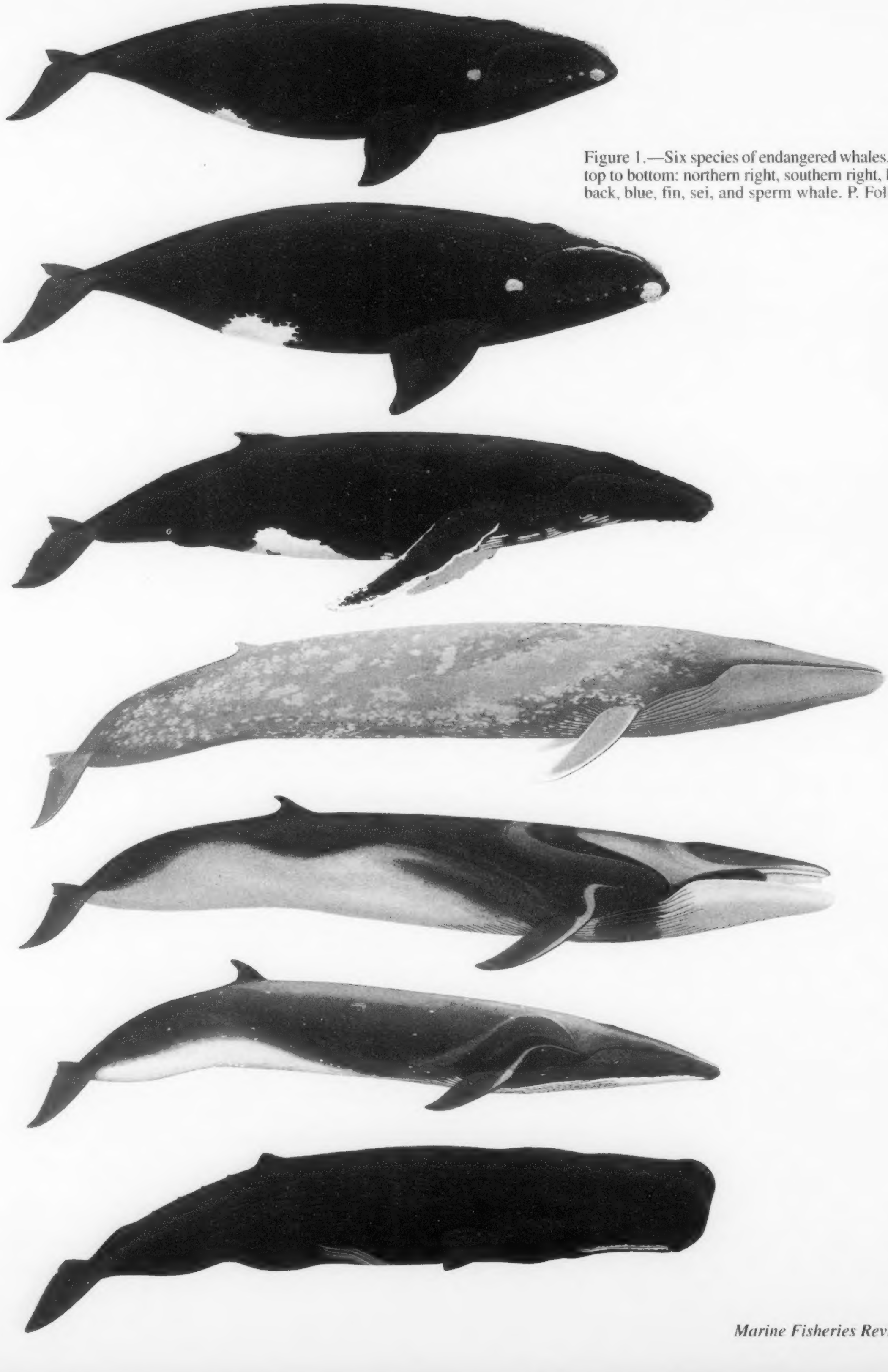


Figure 1.—Six species of endangered whales. From top to bottom: northern right, southern right, humpback, blue, fin, sei, and sperm whale. P. Folkens.

species of large whales were not included in this volume because 1) the eastern North Pacific stock of gray whale was removed from the endangered species list in June 1994 and 2) a status review of bowhead whale stocks was recently published (Shelden and Rugh, 1995).

As defined in the ESA, a species[2] should be classified as endangered if it is in danger of extinction throughout all or a significant portion of its range as a result of any one of the five factors specified in Section 4(a)(1) (Table 1). In addition, a species should be classified as threatened if it is likely to become endangered in the foreseeable future due to any of the factors listed in Table 1.

On 10 November 1978, the U.S. Congress passed Public Law 95-632, which amended the ESA and required the Secretaries of Commerce and Interior to review the status and degree of endangerment of all species on the List at least once every 5 years. Within the 5-year status report, the results of a determination are to be reported as to whether a listed species should be 1) removed from the list, 2) reclassified from endangered to threatened, or 3) reclassified from threatened to endangered. In response to this Congressional mandate, the National Marine Mammal Laboratory of NOAA's National Marine Fisheries Service (NMFS) began its first such review in 1982, publishing the status reports jointly in the *Marine Fisheries Review* (Rice et al., 1984; Mizroch et al., 1984a, b, c; Johnson and Wolman, 1984; Braham and Rice, 1984; Braham, 1984a; and Gosho et al., 1984). Braham (1984b) reported in a summary article that only the eastern North Pacific stock of gray whale and perhaps the western North Atlantic stock of humpback whale may have recovered to levels approaching their preexploitation population size. He further noted that "On the basis of population size alone, these two stocks plus most sperm whale stocks seem likely candidates for reclassification. However, population size is not the only criteria to be considered in deciding whether a stock warrants continued protection under the ESA."

[2] In the implementation of the ESA, the term species has been interpreted to mean "any distinct population segment of any species of vertebrate, fish, or wildlife, which interbreeds when mature" (ESA§3[16], as amended in 1978).

Table 1.—Summary of factors for listing a species as threatened or endangered under authority of the ESA (ESA § 4 (a)(1)). Only one factor is needed for classification.

1. The present or threatened destruction, modification, or curtailment of a species' habitat or range.
2. Overutilization for commercial, recreational, scientific, or educational purposes.
3. Disease or predation.
4. The inadequacy of existing regulatory mechanisms.
5. Other natural or manmade factors affecting a species' continued existence.

In the 14 years that followed, there were no formal status reviews or publications produced similar to the 1984 issue (46(4)) of the *Marine Fisheries Review*. However, several significant actions regarding the status of endangered species of large whales took place. First, from 1984 to 1998 the International Whaling Commission (IWC) continued to review the status of all stocks of large whales and to make management recommendations when there was agreement within the Commission. For example, the IWC imposed a moratorium on commercial whaling for all stocks starting with the 1986 coastal and the 1985–86 pelagic seasons (IWC, 1995b).

Although the Government of Norway formally objected to the classification of the northeastern stock of minke whales as a "Protected Stock" (i.e. a stock for which commercial whaling was not allowed) and therefore was not bound by the IWC moratorium for this stock, there were no objections to the moratorium for any of the species listed under the ESA (IWC, 1995b). In addition, the IWC continued to manage the aboriginal subsistence harvest for the following stocks of large whales: Bering-Chukchi-Beaufort stock of bowhead whale, eastern North Pacific stock of gray whale, west Greenland and central North Atlantic stocks of minke whale, west Greenland stock of fin whale, and the North Atlantic stock of humpback whale (IWC, 1995b). Because aboriginal whaling quotas are set by the IWC for a specified time period, comprehensive status reviews for most of the stocks taken by aboriginal hunters were performed every 3–5 years.

Braham[3] completed a status update of endangered whales in April 1991. While this report was never formally published, it was widely distributed. In that report, Braham noted the following: 1) the eastern North Pacific gray and sperm whale stocks were not in danger of becoming extinct and were not threatened with becoming endangered in the foreseeable future (i.e. recommendation to delist), 2) the Bering-Chukchi-Beaufort bowhead whale stock was not in danger of becoming extinct in the foreseeable future (i.e. recommendation to downlist to threatened), and 3) all other stocks of large whales were either severely depleted or the data were inconclusive to warrant changing their current listing status of endangered.

In 1991 the NMFS published Recovery Plans for two species of large whales: Final Recovery Plan for the northern right whale (Anonymous, 1991a) and Final Recovery Plan for the humpback whale (Anonymous, 1991b). In each of these Recovery Plans, the status of stocks within U.S. waters was reviewed. Further, while definitions of endangered and threatened for the western North Atlantic stock of right whale and the definition of threatened for stocks of North Pacific and North Atlantic humpback whales were provided in the Plans (Table 2), their relevance to the ESA definitions of endangered and threatened has been questioned (DeMaster and Gerber[4]; Shelden[5]).

A summary of environmental threats to baleen whales was recently completed by Clapham and Brownell[6]. In

[3] Braham, H. W. 1991. Endangered whales: status update. Unpubl. doc., 56 p., on file at Natl. Mar. Mammal Lab., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

[4] DeMaster, D., and L. Gerber. 1997. A new approach to classifying the central North Pacific stock of humpback whales under the U.S. Endangered Species Act. NMFS Alaska Fisheries Science Center *Quarterly Report*, Oct.-Nov.-Dec. 1997, p. 1–4.

[5] Shelden, K. W. 1998. The bowhead whale: a case study for development of criteria for classification on the List of Endangered and Threatened Wildlife. Master's thesis, School Mar. Affairs, Univ. Wash., Seattle, 137 p.

[6] Clapham, P. J., and R. L. Brownell, Jr. 1999. Vulnerability of migratory baleen whales to ecosystem degradation. Convention of Migratory Species Special Publications (In press). Rep. avail. from P. J. Clapham, NEFSC, 166 Water St., Woods Hole, MA 02543-1097.

Table 2.—Summary of criteria for downlisting Northern Hemisphere right and humpback whales as reported in recovery plans for each species (Anonymous, 1991a, 1991b).

	Criteria	
Stock	Endangered	Threatened
North Pacific right whale	Not developed	Not developed
Western North Atlantic right whale	1. Population <6,000 2. Population not increasing at 2% per year over 20-year period. 3. No effective program in place to control mortality.	Population <7,000
North Pacific humpback whale	Not developed	Population <0.6 of *K*
North Atlantic humpback whale	Not developed	Population <0.6 of *K*

addition, the NMFS has completed a Recovery Plan for North Pacific and North Atlantic blue whale stocks (Anonymous, 1998), and efforts are now focused on the completion of a Recovery Plan for the North Pacific and North Atlantic stocks of fin and sei whales (Anonymous[7]). Completion of the fin and sei whale Recovery Plan is expected in 1999.

An additional action concerning the status of listed stocks of large whales involved the gray whale. In November 1991 the NMFS issued a proposed determination that the eastern North Pacific stock of gray whales be removed from the List. The NMFS issued a final determination to delist on 7 January 1993, but concurrence from the U.S. Fish and Wildlife Service (FWS) was not received until June 1994, when this stock was officially removed from the List. This delisting was the first such action for any species of marine mammal since the passage of the ESA in 1973. As a part of the delisting process, in 1993 the NMFS also developed a 5-year plan for research and monitoring[8]. The development of such a plan is a requirement of the ESA, where the agency responsible for management (i.e. U.S. Department of Commerce for cetaceans) must commit to monitor the status of the delisted stock for a period of at least 5 years following delisting. If at any time during this period the Secretary of Commerce finds that the species' well-being is at risk, the ESA provides that emergency protective regulations, under Section 4(b)(7), shall be issued by the Secretary to ensure the conservation of any recently delisted species. As part of the 5-year plan for research and monitoring, the NMFS conducted three biennial surveys during southbound migrations for the purposes of estimating annual abundance and determining trends in abundance and four annual surveys during northbound migrations for the purpose of estimating calf production. Also required as part of the delisting process is a formal review of the status of a delisted stock 5 years following the action to delist. A workshop was held during the spring of 1999 to review the status of the eastern stock of North Pacific gray whale.

Shelden and Rugh (1995) published a formal status review of the bowhead whale, which included a status summary of the five recognized stocks. No specific recommendations to change the listing status of any of these bowhead whale stocks were proposed by them. However, they did report that NMFS would undertake to develop objective criteria to determine whether the current classification of one of these stocks, bowhead whales of the Bering-Chukchi-Beaufort Seas, is accurate (Shelden[5]).

The following report officially updates the status of the remainder of the stocks of endangered large whales (i.e. right, humpback, blue, fin, sei, and sperm whales). In the remainder of this overview, we summarize problems that have been identified in defining classification criteria under the ESA, discuss possible changes to the classification of endangered large whale stocks, and provide an update on the currently listed large whale species (except bowhead whales).

[7] Anonymous. 1999. Draft recovery plan for the fin whale, *Balaenoptera physalus* and sei whale *Balaenoptera borealis*, 68 p. Avail. from F/OPR, NMFS, NOAA, 1315 East-West Highway, Silver Spring, MD 20910.

[8] Braham, H. W., and D. P. DeMaster (Editors). 1993. A 5-year plan for research and monitoring of the eastern North Pacific population of gray whale. Unpubl. doc., 54 p., prep. for the Asst. Admin. Fish., NOAA, 1315 East-West Highway, Silver Spring, MD 20910.

Problems with Marine Mammal Classification Under the Endangered Species Act

One of the most difficult problems in implementing the ESA is that objective criteria for what constitutes being in danger of extinction is not defined in the Act or elsewhere (Rohlf, 1991). As already noted by several authors (Tear et al., 1995; Easter-Pilcher, 1996; Shelden[5]) the NMFS and FWS have used an ad hoc and subjective approach to classifying individual species. This has led to considerable disparity in the type and quality of classification criteria among species that are listed. In 1988, the U.S. Congress amended the ESA to require that each Recovery Plan incorporate objective, measurable criteria for recovery (i.e. delisting). Nonetheless, these criteria have yet to be developed for species of large whales for which Recovery Plans exist. Further, the Recovery Plans currently being developed for listed species do not include such criteria (DeMaster and Gerber[4]). Finally, we believe that Congress also intended to have delisting criteria developed for those species for which Recovery Plans have not been developed.

There has been some confusion in the literature between a classification of threatened under the ESA and a classification of depleted under the Marine Mammal Protection Act (MMPA). In some cases, it has been assumed that a population sufficiently large to be classified as healthy under the MMPA (i.e. population greater than 60% of its carrying capacity (*K*)) is also sufficiently large to be removed from the List of Endangered and Threatened Wildlife of the ESA. Unfortunately, there is nothing inherent about the definition of threatened that makes such a relationship valid. To further complicate matters, the status of a population relative to its carrying capacity (*K*) is not necessarily well correlated with the probability of extinction in the foreseeable future. Obviously, populations at very low status levels (e.g. less than 10% of *K*) are often very small in number and therefore more likely to become extinct over a given period of time than a population several times larger. However,

over a wide range of population sizes, status relative to K alone is not a good predictor as to whether extinction is imminent.

The World Conservation Union (IUCN) recently developed objective classification criteria for the purposes of identifying species that are, or may be, threatened with extinction (IUCN, 1996). As noted in Gnam (1993) and Shelden[5], these criteria seemed to have been developed with terrestrial species in mind, and some of the definitions or parameters used in the criteria are not easily applied to marine species. For example, one of the criteria refers to the area of occurrence, but it is not clear how to apply such a criterion to species like large whales that migrate over great distances. Nonetheless, this approach represents a significant improvement over the ad hoc system previously used by the NMFS and FWS. As noted by DeMaster and Gerber[4], the IUCN criteria can be modified to make the criteria more pertinent to marine species, including species of large whales.

Most endangered whale species occur in geographically and, in some cases, genetically discrete populations. These populations are typically referred to as stocks, and may be designated on the basis of species' biology, management objectives, or a combination of biological and management goals. However, since biological information necessary to make reliable stock structure determinations is generally lacking for the large whales, management objectives tend to play a large role in how stocks are designated (Barlow[9]).

Two different approaches for stock designation are referred to in this document. The first of these approaches has been adopted by the NMFS in the production of annual stock assessment reports. As a default in the absence of biological data, the NMFS approach defines stock structure relative to discontinuities in the distribution of the stock in question and relative to the distribution of commercial fisheries in the North Pacific and North Atlantic Oceans (Barlow et al., 1995a). The second approach uses stock determinations currently recognized by the IWC (Donovan, 1991). The former approach uses smaller areas to define the range of a stock than does the latter, and has been adopted in an effort to minimize the risk of adverse interactions between commercial fisheries and marine mammals. The latter approach generally uses much larger areas to designate stocks (i.e. typically an ocean basin). While detailed evaluation of the merits of these two approaches is beyond the scope of this report, we summarize the status of six endangered large whale species based on current stock designations that currently rely on these approaches (Tables 3, 4, 5).

Summary and Recommendations Regarding the Listing Status of Large Whales

As discussed above, all large whale species currently listed as endangered under the ESA were severely depleted as a result of commercial whaling. The effects of low population size and the continued threat of overexploitation were the primary reasons that the species were first listed. Because commercial overexploitation is no longer imminent, or at least is greatly diminished, the listed species could, theoretically, be delisted. However, the potential for adverse effects from human activities still exists, and the lingering effects of low population size do remain (Clapham et al. [10]). For example, northern right whale stocks, which are still severely depleted, have shown no sign of recovery or at least no substantial population growth in the last two decades even though local commercial hunting ceased in 1949 (Anonymous, 1991a). Clearly, the listing classification of this species should remain (Table 5).

Stock identity of North Atlantic and North Pacific humpback whales is relatively well understood, and some humpback whale populations are showing significant increases (see the review beginning on page 24). Most notable are the western North Atlantic and the central North Pacific stocks. For example, Smith et al.[11] estimated there are 5,543 whales in the western North Atlantic, which may be greater than estimated preexploitation levels (Table 4). As population estimates are refined, population structure is better understood, and as mortality and serious injury from human activities are reduced, these stocks may be considered for downlisting or delisting if the appropriate long-term monitoring programs can be established (Table 5).

Table 3.—Available potential biological removal (PBR) levels for five species of endangered whales from Hill and DeMaster (1998); Barlow et al. (1997); Waring et al. (1998). PBR = product of N_{min}, 1/2 maximum net productivity rate, and a specified "recovery" factor for endangered stocks, threatened stocks, or stocks of unknown status relative to OSP (Wade and Angliss, 1997). Stocks without PBR indicate that data were insufficient.

Species	Stock	PBR
Northern right whale	Western North Atlantic	0.4
Humpback whale	Western North Pacific	0.7
	Central North Pacific	7.4
	CA/OR/WA and Mexico	1.1
	CA/OR/WA (U.S. only)	0.5
	Western North Atlantic	9.7
Blue whale	CA and Mexico	2.9
	CA (U.S. only)	1.5
	Western North Atlantic	0.6
Fin whale	CA/OR/WA	2.1
	Western North Atlantic	3.4
Sperm whale	CA/OR/WA	1.8
	Western North Atlantic	3.2
	Northern Gulf of Mexico	0.8

Blue whale stocks off the west coast of North America also show signs of growth. For example, the stock of blue whales that feed in waters off California, Oregon, and Washington, which was once thought to include fewer than 500 individuals, was recently estimated at 1,785 (CV = 0.24; Barlow et al., 1997). While additional data are still needed on stock structure, trends in abundance, and habitat requirements, this stock may be a candidate for downlisting as long as reliable monitoring programs are established and long-term research is continued (Table 5).

In contrast, for several other species there is insufficient information about stock structure and abundance to make determinations regarding changes in listing status at this time (Table 5). These

[9] Barlow, J. 1998. Chief Scientist, Southwest Fisheries Science Center, NMFS, P.O. Box 271, La Jolla, CA 92038. Personal commun.

[10] Citation updated in proof: see Clapham et al., 1999 in literature cited.

[11] Citation updated in proof: see Smith et al., 1999 in literature cited.

Table 4.—Estimates of pre-exploitation ("initial") and current ("recent") population sizes for six large whale species currently listed as "endangered" under the ESA. See text for references and estimates CV, CI, and ranges (N.e.= no published estimate).

Species	Population Estimate: Initial	Recent
Right Whale		
North Pacific		
Total	N.e.	N.e.
Eastern North Pacific	N.e.	100–500
Sea of Okhotsk[1]	N.e.	900
Western North Atlantic	N.e.	300–500
Eastern North Atlantic	N.e.	N.e.
Southern Hemisphere	N.e.	7,000
Humpback Whale		
North Pacific		
Total	N.e.	6,000–8,000
Western North Pacific	N.e.	394
Central North Pacific	N.e.	4,005
North Atlantic		
Total	N.e.	10,600
Western North Atlantic	N.e.	N.e.
Eastern North Atlantic	N.e.	N.e.
Southern Hemisphere	N.e.	17,000
Blue Whale		
North Pacific		
Total	N.e.	1,600
CA/OR/WA[2]	N.e.	1,930
Western North Atlantic	N.e.	100–560
Northern Indian Ocean	N.e.	N.e.
Southern Indian Ocean[3]	N.e.	5,000
Southern Hemisphere	N.e.	1,260
Fin Whale		
North Pacific	N.e.	14,620–18,630
Western North Atlantic	N.e.	3,590–6,300
East Greenland/Iceland	N.e.	11,560
British Isles/Spain and Portugal	N.e.	4,490–17,360
Southern Hemisphere	N.e.	85,200
Sei Whale		
North Pacific	N.e.	9,110
North Atlantic		
Total	N.e.	4,000
Iceland/Davis Strait	N.e.	1,590
Nova Scotia	N.e.	1,390–2,250
Labrador Sea	N.e.	N.e.
Southern Hemisphere	N.e.	9,720–12,000
Sperm Whale		
North Pacific		
Total	N.e.	N.e.
CA/OR/WA[2,4]	N.e.	995
Western North Pacific	N.e.	N.e.
Eastern North Pacific	N.e.	N.e.
North Atlantic		
Total	N.e.	N.e.
Western North Atlantic	N.e.	220–2,700
Northern Gulf of Mexico	N.e.	530
Iceland	N.e.	1,230
Azores	N.e.	N.e.
Spain	N.e.	N.e.
Northern Indian Ocean	N.e.	N.e.
Southern Hemisphere		
Total	N.e.	N.e.
South of 60°S	N.e.	3,200–14,000
South of 30°S	N.e.	128,000–290,000
Equatorial East Pacific	N.e.	3,891

[1] Recent estimate 95% CI = 404–2,108 (from IWC, 1998, Workshop on the Comprehensive Assessment of Right Whales, Unpubl. Doc. SC/50/REP4).
[2] CA/OR/WA = California/Oregon/Washington
[3] Pygmy blue whale only
[4] Recent minimum population estimate (N_{min}) from Barlow (text footnote 75).

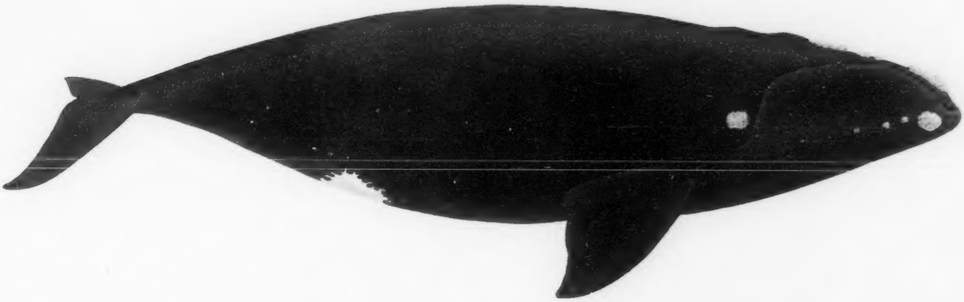
Table 5.—A general evaluation of the possible recovery of endangered large whales by stock or region. Note: Stocks and regions listed represent current knowledge on distribution and density. These are not formal stock designations.

Status
Perhaps recovered[1]
Central North Pacific humpback whale
Western North Atlantic humpback whale
California, Oregon, Washington blue whale
British Isles/Spain & Portugal fin whale
Depleted[2]
Southern Hemisphere right whale
Western North Pacific humpback whale
Southern Hemisphere humpback whale
North Pacific blue whale
Western North Atlantic blue whale
Southern Hemisphere blue whale
Southern Indian Ocean (pygmy) blue whale
Southern Hemisphere fin whale
North Pacific fin whale
Western North Atlantic fin whale
North Pacific sei whale
Southern Hemisphere sei whale
Iceland sperm whale
Critically low population level[3]
North Pacific right whale
Western North Atlantic right whale
Insufficient data for judgment
Eastern North Atlantic right whale
Eastern North Atlantic humpback whale
Northern Indian Ocean blue whale
East Greenland/Iceland fin whale
Iceland/Davis Strait sei whale
Nova Scotia sei whale
All sperm whale stocks

[1] Recent population abundance estimate at or near population size prior to commercial whaling.
[2] Well below initial population size estimates, but may include low populations that have shown some recent increase (e.g. Southern Hemisphere right whales).
[3] Recent population estimates number in the tens to hundreds.

include fin, sei, and sperm whales. Therefore, while the abundance of some stocks may be increasing or their total abundance in any given ocean basin is relatively large (e.g. sperm whale), data on stock structure and habitat requirements are too inconclusive to warrant changing their listing status in the near future.

The comprehensive status reviews that follow are based on published literature from about 1980 through 1998. In some instances, where important data remains unpublished, we have cited personal communications, manuscripts in press, and draft documents. In other instances, where no new data has been collected since the 1984 reviews, we have cited pre-1980 literature. Scientists continue to develop new methods of gathering and analyzing population data, thus expanding our knowledge of large whale population biology; however, new and important publications after early 1999 were excluded from these reviews for the sake of timeliness. As it stands, these reviews are already more than 10 years later than the Congressionally mandated 5-year review period.



The Right Whales

Introduction

The right whales, *Eubalaena* spp., are identified by their robust body, black coloration, lack of a dorsal fin, callosities on the head region, and large, strongly bowed lower jaw (Fig. 2). While nomenclature for this species varies, (some authors use the genus *Balaena* spp. (Braham and Rice, 1984; Rice[12]), they are referred to under the genus *Eubalaena* spp. by the IWC (Hershkovitz, 1966; Schevill, 1986). The Northern and Southern Hemisphere species have been taxonomically separated based on skeletal data (Müller, 1954; Schaeff et al., 1991; Rice[12]). A genetic study of the right whale mitochondrial DNA control region suggests that this current taxonomical separation is not valid, but through phylogenetic analysis of mitochondrial lineages there is evidence of independent taxonomic status for right whales in the North Pacific, North Atlantic, and Southern Oceans (Rosenbaum et al.[13]). In this review, Northern Hemisphere right whales will be referred to as *Eubalaena glacialis glacialis* Muller 1776, and the Southern Hemisphere right whales will be referred to as *E. g. australis* Desmoulins 1822 after Rice[12] and IWC designations.

Northern right whales are now the most endangered of the large whales. Recent data indicate that there is a small but unknown number of individuals in the eastern North Pacific, and that there are approximately 300 individuals in the western North Atlantic (Carretta et al., 1994; Goddard and Rugh, 1998; Knowlton et al., 1994). Southern right whales, in contrast, have shown signs of recovery over the past 20 years (Bannister, 1990; Best, 1990; Payne, 1990). The scarcity of right whales is the result of an 800-year history of whaling that continued into the 1960's (Klumov, 1962) or as late as 1980 (Zemsky et al., 1995).

Northern right whales have been protected for more than 60 years from commercial whaling, yet their numbers remain low. In the North Pacific, the wide distribution of such low numbers of animals may have diminished mating

[12] Citation updated in proof: see Rice, 1998 in literature cited.

[13] Rosenbaum, H., R. L. Brownell Jr., M. Brown, C. Schaeff, V. Portway, B. White, S. Malik, L. Pastene, P. B. Best, P. J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C. Tynan, and R. Desalle. 1998. A genetic review of inter-relationships between right whales in different ocean areas. Unpubl. doc. SC/M989/RW23 submitted to the IWC Workshop on the Comprehensive Assessment of Right Whales, Cape Town, South Africa, May 1998.

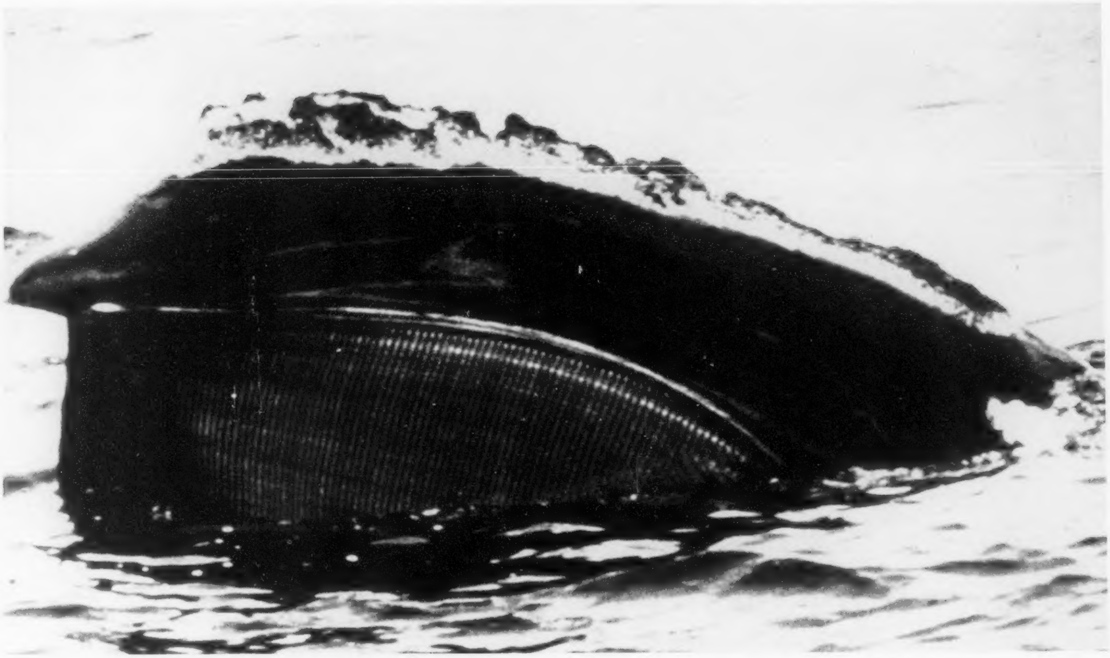


Figure 2.—A right whale skimming the water's surface for its zooplankton prey. Notice the whitish callosities and dark colored baleen. (W. A. Watkins, NMML Collection)

opportunities; therefore, chances of recovery for this stock appear bleak (Braham and Rice, 1984). At least in the North Atlantic, human interactions (e.g. vessel strikes and fisheries entanglements) on their coastal calving grounds and elsewhere are thought to be one of the predominate factors keeping abundance levels low.

Distribution and Migration

Right whales have occurred historically in all the world's oceans from temperate to subarctic latitudes (Fig. 3). Right whales prefer shallow coastal waters, but their distribution is also strongly correlated to the distribution of their zooplankton prey. In both hemispheres, they have been observed in low latitudes and nearshore waters during winter, where calving takes place, and they tend to migrate to high latitudes during the summer. In the North Atlantic and Southern Hemisphere, it appears that not all reproductively active females return to the calving grounds each year (Kraus et al., 1986; Payne, 1986). Right whale distribution in summer and fall in both hemispheres is likely linked to the patchy distribution of their principal zooplankton prey (Winn et al., 1986).

North Pacific

Historically, right whales ranged across the entire North Pacific north of lat. 35°N (Braham and Rice, 1984). Sightings in the 20th century are from as far south as the Yellow Sea and central Baja California to as far north as the Okhotsk Sea and the Bering Sea (Fig. 4, 5) (Scarff, 1986). The IWC recognizes North Pacific right whales as one contiguous stock, stating that at this time there is not enough evidence on their specific distribution to designate otherwise (IWC, 1986a). During the 1983 IWC Right Whale Workshop (IWC, 1986a), the Scientific Committee recommended distinguishing two stocks, one in the east and one in the west, but it stated "no conclusion can be reached concerning the identity of biological populations." At the 1998 IWC Right Whale Comprehensive Assessment Workshop[14], it was tentatively decided that there was insufficient data about where calving and breeding take place to confirm or deny the existence of more than one stock in the North Pacific. However, several preliminary recommendations regarding North Pacific stock structure were made during this 1998 workshop. First, the western area of the North Pacific should be designated a management unit based on current sighting information. Second, the current east and west separation should stay in place until new data become available. And third, additional genetic analysis using historical samples should be undertaken (IWC[14]).

Lack of data on calving area locations in the North Pacific and a number of sightings of right whale concentrations in the mid Pacific north of Hawaii, have challenged the separation of eastern and

[14] IWC. 1998. Draft report of the workshop on a comprehensive assessment of right whales: a worldwide comparison. Unpubl. doc. SC/50/Rep4 submitted by the Scientific Committee to the IWC, Cape Town, South Africa, May 1998.

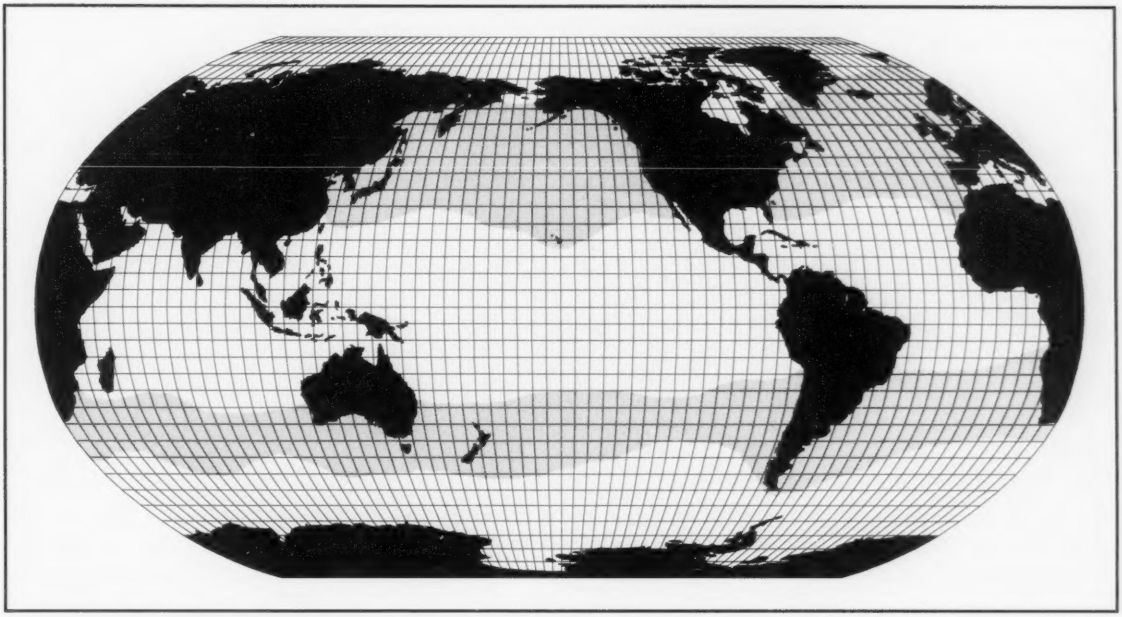


Figure 3.—Historic worldwide right whale distribution. Adapted from Braham and Rice (1984).

western stocks in the North Pacific (Scarff, 1986). Some researchers have suggested the possibility of two western North Pacific right whale stocks because of differences in migration routes and summer ranges: one traveling into the Okhotsk Sea and the other to the east of the Kuril Islands and Kamchatka Peninsula during summer (Klumov, 1962; Omura, 1986). Furthermore, the relative scarcity of current and historic sighting records from the eastern North Pacific (despite historic whaling in British Columbia) suggests that, if a separate eastern North Pacific right whale stock exists, it may be close to extinction (Braham and Rice, 1984; Scarff, 1986).

Historical whaling records provide the only information on possible migration patterns for North Pacific right whales (Scarff, 1986). During summer, whales were found in the Okhotsk Sea, along the east coast of the Kamchatka Peninsula, the Kuril Islands, south of the Aleutian Islands, the Bering Sea (Bristol Bay), and the Gulf of Alaska (Fig. 4, 5). The fall and spring distribution was the most widely dispersed, with whales found in mid ocean waters and spanning from the Sea of Japan to the eastern Bering Sea. In winter, the whales were found in the Ryukyu Islands (south of Kyushu, Japan), the Bonin (Ogasawari) Islands, the Yellow Sea, and the Sea of Japan (Fig. 5). The current distribution patterns and migration routes of these whales are not known.

In the 20th century, individual right whale sightings have been scarce and geographically scattered in the North Pacific. For example, a lone right whale was sighted off San Clemente Island, Calif. (Fig. 4) in 1992. This was only the twelfth reliable right whale sighting of this century in the eastern North Pacific (Carretta et al., 1994). The animal was photogrammetrically measured to be 12.6 m (SD = 0.6 m), a relatively small animal, perhaps not yet sexually mature (Carretta[15]). In July 1996, a group of right whales was sighted in western Bristol Bay (Fig. 4) (Goddard and Rugh, 1998). The group consisted of four individuals, one of which was considerably smaller than the others. This was one of the first sightings of a group of right whales in the northeast Pacific this century, although sightings of individual animals have occurred more frequently (Goddard and Rugh, 1998).

The Bristol Bay sighting was followed by another confirmed sighting in September of a group of four individuals 108 km southwest of the July sighting (Goddard and Rugh, 1998). These are only the fourth and fifth reliable sightings of right whales in the Bering Sea since 1975.[16] There are insufficient good quality photographs to confirm resightings of particular individuals, but increased search effort and reporting of sightings to the appropriate investigators is resulting in a better understanding of where these whales occur.

North Atlantic

The IWC recognizes two right whale stocks in the North Atlantic: western

[15] Carretta, J. 1997. NMFS Southwest Fisheries Science Center, La Jolla, CA 92038. Personal commun.

[16] Platform of Opportunity Program 1975-1996. Unpubl. data on file at NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

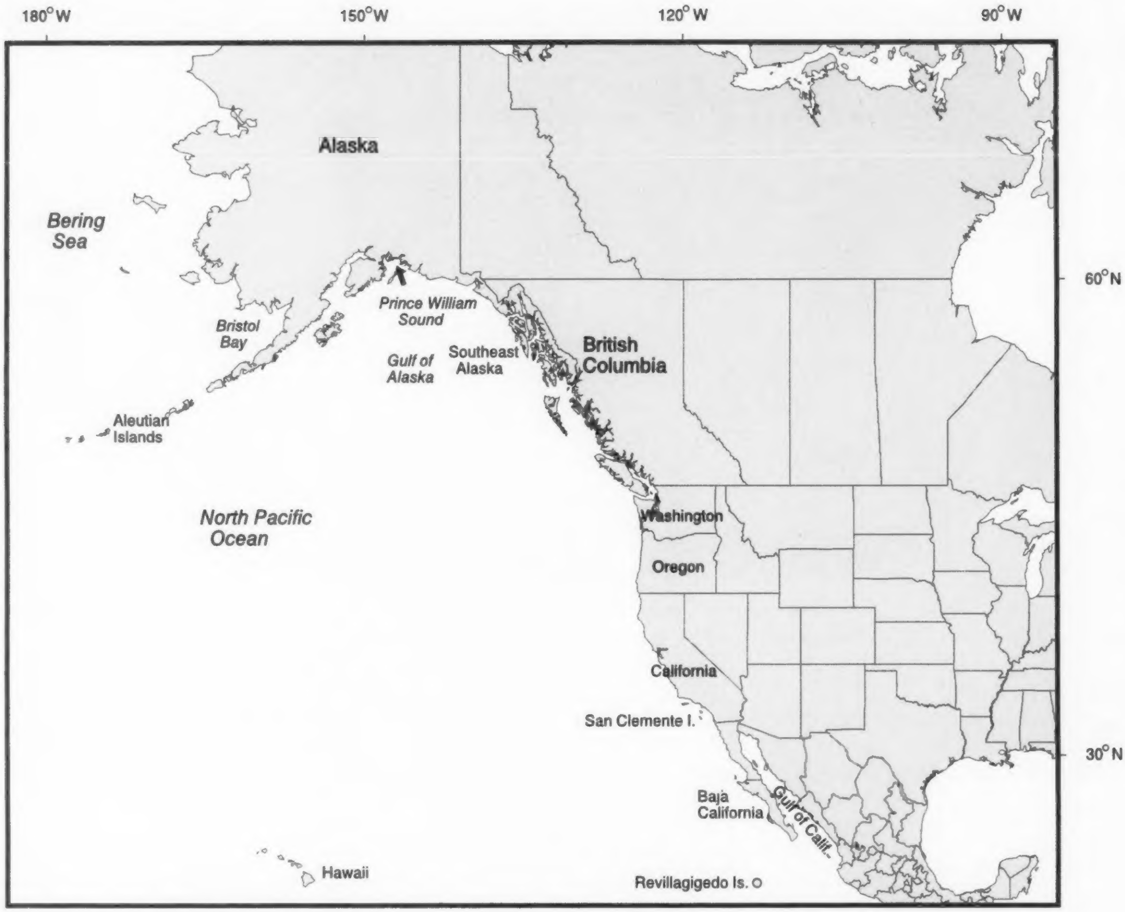


Figure 4.—Eastern North Pacific region.

and eastern (IWC, 1986a). The western stock migrates along the North American coast from Nova Scotia to Florida (Fig. 6). The eastern stock was historically hunted by whalers along coastal Iceland, off the British Isles, in the Bay of Biscay, and in Cintra Bay (Fig. 7). From whaling records, it appears that these whales migrated along the coast from northern Europe to northwest Africa. Today the distribution and migration patterns of this eastern stock are unknown. There is also evidence from whaling records that a third stock may have existed in the central Atlantic Ocean, migrating from east of Greenland to the Azores or Bermuda (Fig. 6, 7) (Reeves and Mitchell, 1986).

In the western North Atlantic, five areas of "high use" were identified in the final recovery plan for the northern right whale (Fig. 8) (Anonymous, 1991a):

1) Coastal Florida and Georgia (Sebastian Inlet, Florida to mid-coast Georgia),
2) The Great South Channel (east of Cape Cod),
3) Massachusetts Bay and eastern Cape Cod Bay,
4) The Bay of Fundy, and
5) Browns and Baccaro Banks (south of Nova Scotia).

These areas were designated as northern right whale critical habitat[17] due to their importance to the reproductive and feeding activities of the species (Kraus and Kenney[18]). Generally, right whales occur off New England in spring and

[17] Under Section 4 of the ESA, "critical habitat" must be designated "on the basis of the best scientific data available and after taking into consideration the economic impact." Critical habitat is defined under Section 3 of the ESA as "specific areas within the geographical area occupied by the species....on which are found physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection." Except under special circumstances, critical habitat shall not include the entire geographical area occupied by the species. (See also Fed. Regist. 50 CFR pt. 226, Designated critical habitat.)

[18] Kraus, S. D., and R. D. Kenney. 1991. Information on right whales (*Eubaleana glacialis*) in three proposed critical habitats in U.S. waters of the western North Atlantic Ocean. Final rep. to U.S. Mar. Mamm. Comm., Contr. T-75133740, T-75133753, 64 p., I-vi.

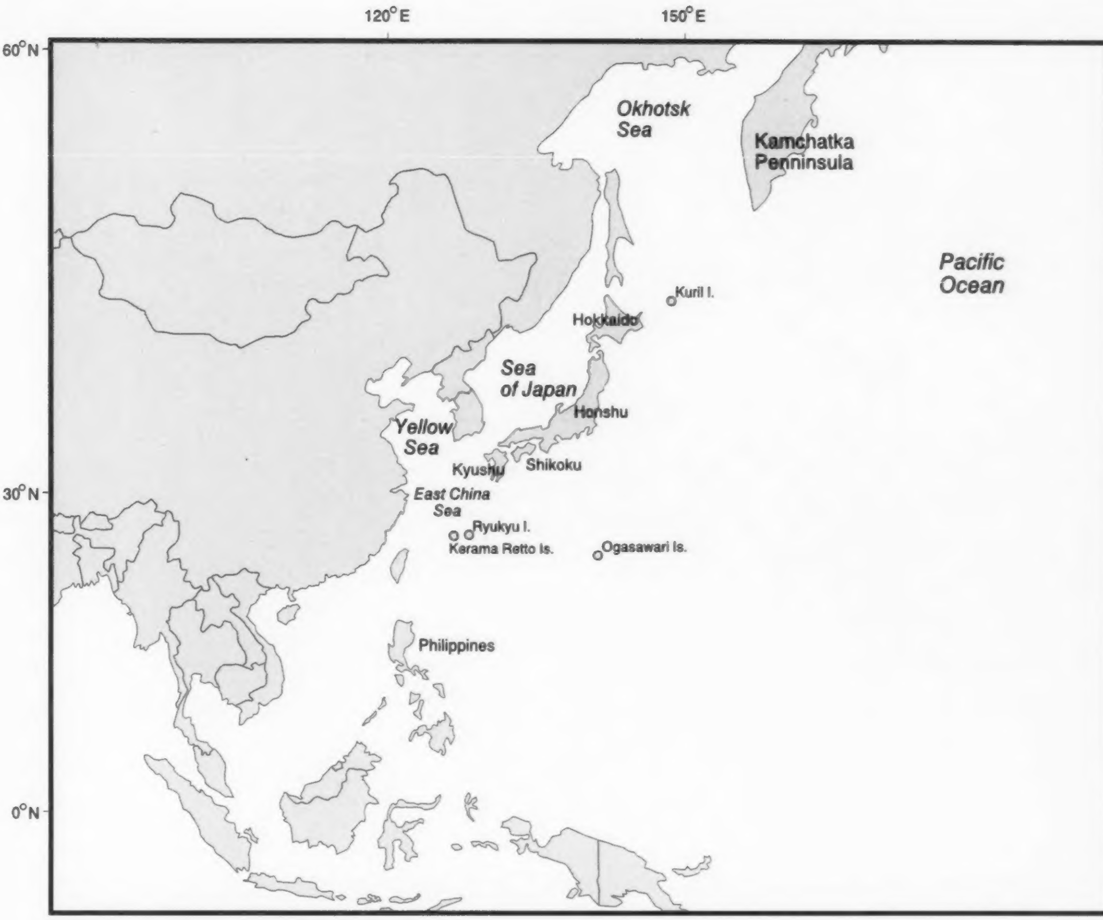


Figure 5.—Western North Pacific region.

early summer. Peak abundance occurs in the Great South Channel along the 100 m isobath and the paralleling thermal front in May (Kenney et al., 1995). In summer and fall, right whales occur farther north into Canadian waters (i.e. the Bay of Fundy and Browns and Baccaro Banks) (Mitchell et al., 1986). Whales found on Browns and Baccaro Banks are predominately adult males, while those in the Bay of Fundy are mostly mother-calf pairs and juveniles. In fall and early winter, the whales move south. Known wintering areas for this stock are along the southeastern U.S. coast, where calving takes place generally from January through March (Brownell et al., 1986; Kraus et al., 1986; Winn[19]). However, the wintering areas for an estimated 85% of the population are unknown (Kraus et al., 1986). Wintering areas may exist in the Gulf of St. Lawrence (Lien et al.[20]), Newfoundland (Beamish, 1981; Lien et al.[20]), Greenland, Bermuda (Payne and McVay, 1971), the Gulf of Mexico (Mead, 1986), and coastal waters of New York and New Jersey (Mead, 1986) (Fig. 6). Telemetry studies have revealed movement patterns of considerable length and duration (Mate et al.[21]). Similar studies may identify additional areas where right whales occur during winter.

Southern Hemisphere

The IWC recognized six stock areas in the Southern Hemisphere (Fig. 9) (Ohsumi and Kasamatsu, 1986; Dono-

[19] Winn, H. E. 1984. Development of a right whale sighting network in the southeastern U.S. Final report for Mar. Mamm. Comm. Contr. MM2324805-6. NTIS PB84-240548, 12 p.

[20] Lien, J., W. Ledwell, and J. Huntington. 1989. Whale and shark entrapments in inshore fishing gear in Newfoundland and Labrador during 1989. Unpubl. rep. to the Newfoundland and Labrador Dep. Fish.and Dep. Fish. Oceans, Can., 30 p.

[21] Mate, B. R., S. Nieukirk, R. Mesecar, and T. Martin. 1992. Application of remote sensing methods for tracking large cetaceans: North Atlantic right whales (*Eubalaena glacialis*). Final rep. to U.S. Dep. Inter., Minerals Manage. Serv., Alaska and Atl. OCS Reg. Off. Contr. 14-12-0001-30411, 167 p.

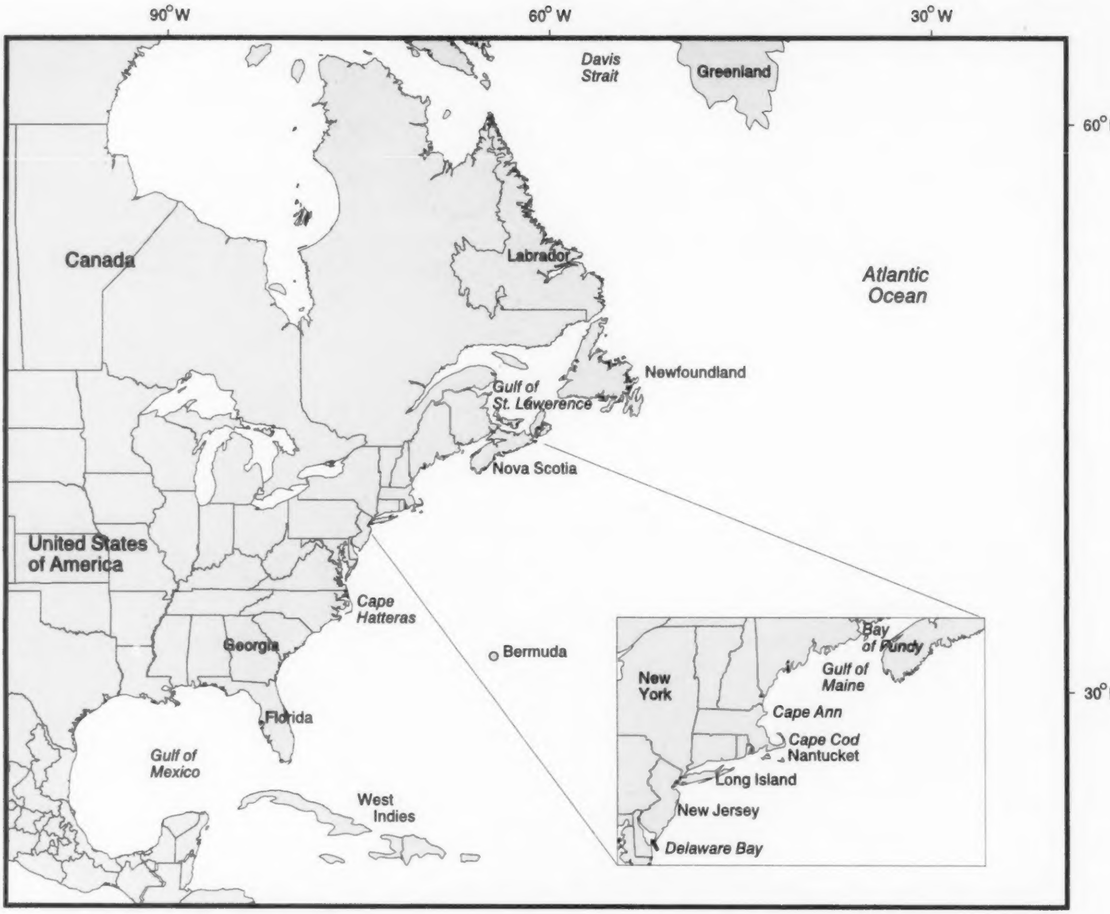


Figure 6.—Western North Atlantic region.

van, 1991). Eight areas were provisionally designated as management units during a 1986 IWC Right Whale Workshop, based loosely on Figure 9, catch histories, and distributional data (IWC, 1986a; Brownell et al., 1986). These eight units were used for mainly statistical purposes. During the 1998 Workshop on the Comprehensive Assessment of Right Whales, a critical evaluation was conducted regarding designation of right whale stock areas for management and statistical purposes. Information considered in this preliminary evaluation included catch histories, recent sighting data, photographic identification, stable isotope analysis, morphology, parasites, and genetic analysis (IWC[14]). This evaluation revealed a complex distribution. There were some preliminary designations of stock separations, but overall no final stock designations for the Southern Hemisphere were made.

Ohsumi and Kasamatsu (1986) reported high concentrations of right whales between the subtropical and Antarctic Convergences (Fig. 10), with the highest density of sightings south of western Australia. These Japanese sighting data indicated that the whales were found farthest south in January (the austral summer) and began moving north in February. This follows the seasonal residence patterns of whales studied in both South Africa and South America, where animals begin arriving on these wintering grounds from May through June, peaking in abundance during September, and then leaving these lower latitudes from December through January (Payne, 1986; Best and Scott, 1993).

Current and Historical Abundance

Most areas where right whales are known to occur have only incomplete catch histories, which confounds any estimates based on back-calculation and

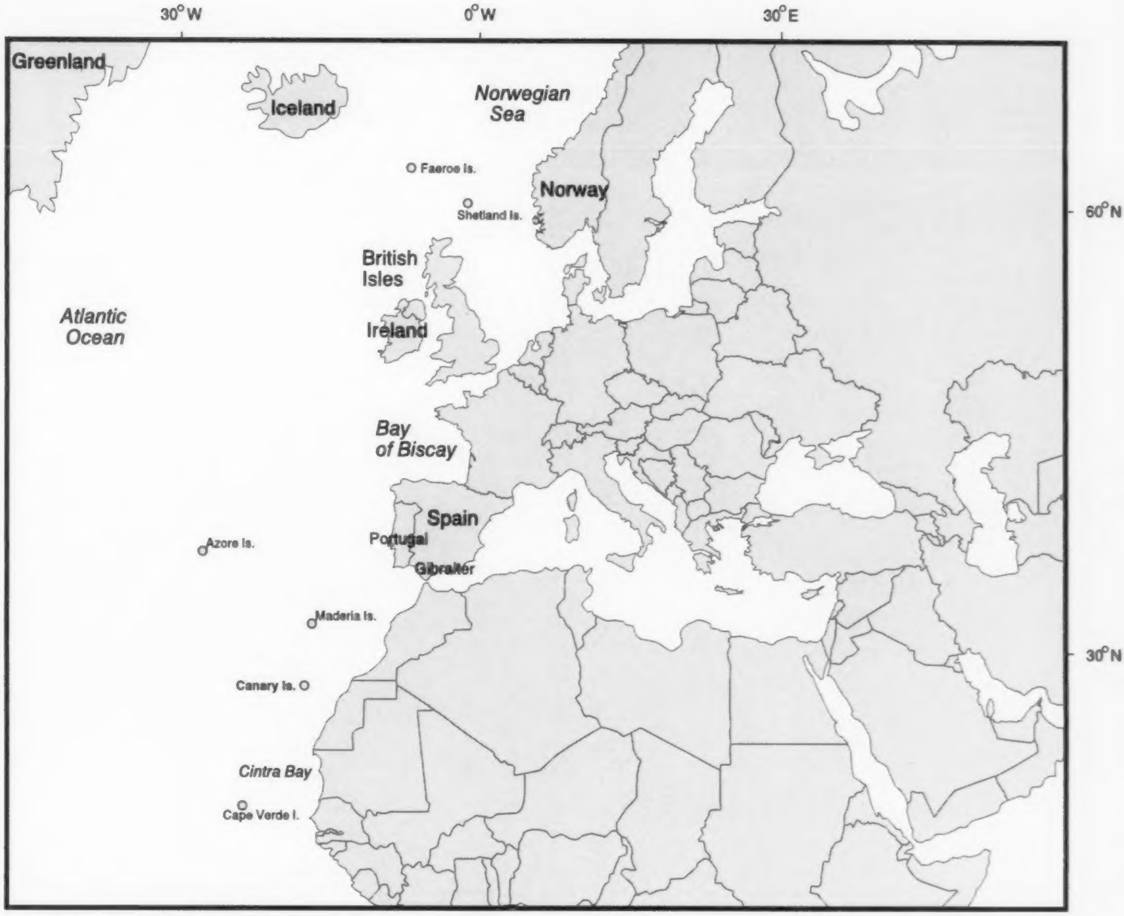


Figure 7.—Eastern North Atlantic region.

catch per unit of effort (CPUE)[22] (IWC, 1986a). What is currently known about right whale abundance and accepted by the scientific community has been summarized in Table 4.

North Pacific

The only population estimate from the North Pacific is for the Okhotsk Sea, a northern right whale summering area. Data from surveys in 1989, 1990, and 1992 have yet to be fully analyzed, but a preliminary analysis indicates the population likely includes only a few hundred animals (Brownell[23]). This estimate has wide confidence intervals and may be negatively biased (IWC[14]).

North Atlantic

In the western North Atlantic, the current best estimate of 300 right whales (Knowlton et al., 1994) is based on photographic identification. Despite uncertainty surrounding this estimate (IWC[14]), it is clear that near failure of calf production from 1993 to 1995, increased calving intervals, and the relatively large number of human-induced mortalities, have contributed to a growing concern over the future of the North Atlantic right whale.

Southern Hemisphere

A preliminary best estimate for total Southern Hemisphere right whale abundance is "about 7,000," based on a tally of estimates from separate breeding areas (IWC[14]). During the 1998 Compre-

[22] From IWC (1992a:238): "In practice, use of 'CPUE' data was abandoned in each of the [*IWC*] management procedures during the later stages of the [*Revised Management Procedure*] development process, in view of the great difficulty usually experienced by the [*Scientific*] Committee in agreeing on the validity and interpretation of such data" [italics added].

[23] Brownell, Robert L. 1998. NMFS Southwest Fisheries Science Center, La Jolla, CA 98038. Personal commun.

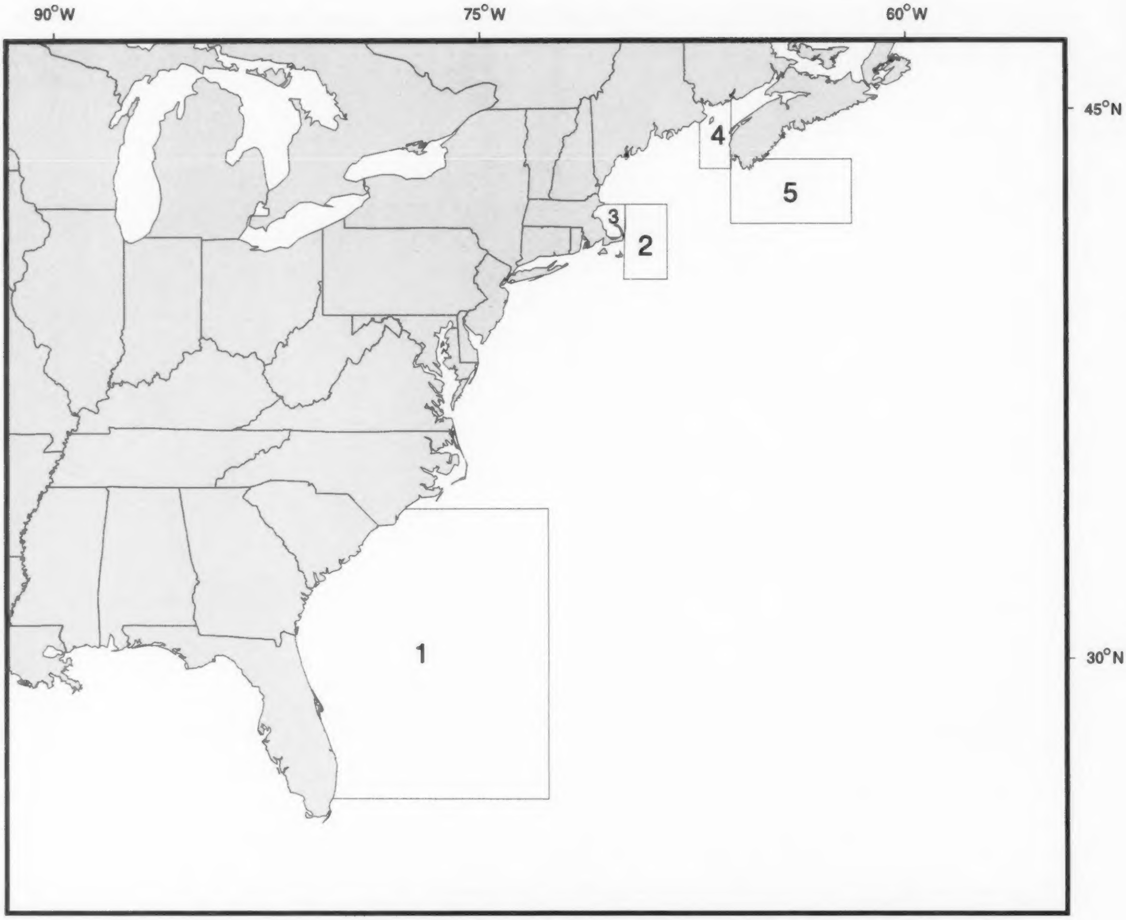


Figure 8.—Western North Atlantic right whale "high-use areas": 1-coastal Florida and Georgia, 2-the Great South Channel, 3-Massachusetts and eastern Cape Cod Bay, 4-Bay of Fundy, 5-Browns and Baccaro Banks (Anonymous, 1991a).

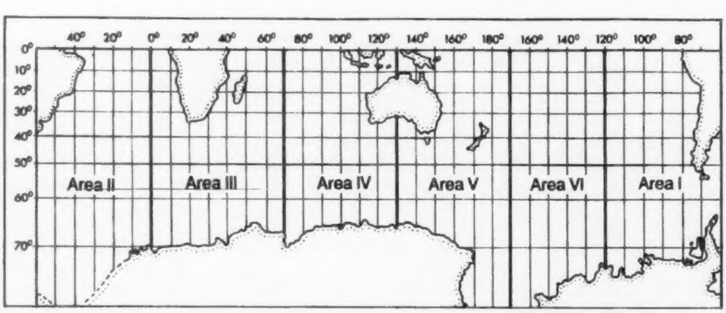


Figure 9.—IWC Southern Hemisphere stock "Area" designations for all endangered baleen whales (Donovan, 1991).

hensive Assessment Workshop, population models were constructed applying this preliminary current estimate and catch history data to a back-calculation simulation using various estimated rates of growth (IWC[14]).

Trends in Abundance

In the North Pacific, there are no data on trends in abundance, but the paucity of sightings strongly suggests there has been little or no growth in this population. As noted above, a number of sightings have occurred in recent years, but this may be linked to increased survey effort.

If the western North Atlantic right whale stock has grown since the period of commercial exploitation, the increase has been modest. The estimated annual

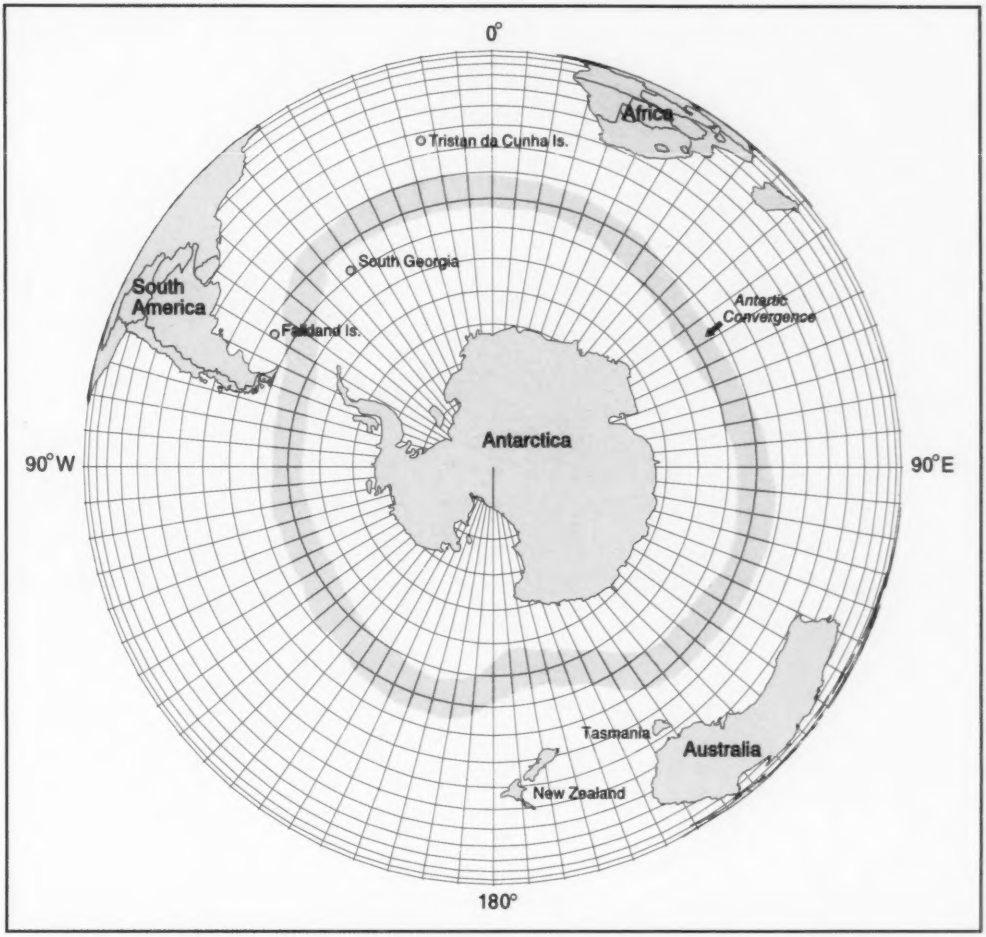


Figure 10.—Antarctic region; shaded area represents approximate location of Antarctic Convergence.

population growth rate from 1986 to 1992 was estimated at 2.5% (CV = 0.12) using photographic identification data (Knowlton et al., 1994). A significant increase in the calving interval for 1985–97 from 3.33 to 5.36 years ($P<0.001$) is further indication that growth and recovery may indeed be slow (Kraus et al.[24]). Kenney et al. (1995) reported a long-term increase in sighting rates within one feeding area of the western North Atlantic (i.e. Great South Channel) of 3.8% per year between 1979 and 1989, but extrapolation of this rate to the entire stock is inappropriate.

In contrast to northern right whale stocks, analysis of reproductive parameters and net recruitment rates for southern right whale stocks reveals a slow, steady rate of recovery. Best (1990) reported an average annual increase of 6.8% (95% CI = 4.6–9.0%) from 1971 to 1987 in right whales occurring off South Africa. However, Butterworth and Best (1990) point out that this stock only occupies 0.1 to 3.0% of its estimated initial (historical) carrying capacity. Right whale abundance increased by 11.7% (95% CI = 4.5–18.9%) to 13.0% (95% CI = 1.3–24.7%) per year from 1977 to 1987 (Bannister, 1990) in waters off western Australia. Payne (1990) reported an annual increase of 7.6% (SE 1.7%) from 1971 to 1986 in the population occurring off Argentina. These rates of increase must be viewed with caution, however, because they are based on only a portion of the population in any given year (i.e. not all mature females return to the calving grounds each year (IWC, 1986a; Best, 1993)), they are not based on any explicit stock designations, and they do not take into account per capita reproductive successes (IWC[14]).

[24] Kraus, S., P. K. Hamilton, R. D. Keeney, A. Knowlton, and C. K. Slay. 1998. Status and trends in reproduction of the North Atlantic right whale. Unpubl. doc. SC/M98/RW1 submitted to the IWC Workshop on the Comprehensive Assessment of Right Whales, Cape Town, South Africa, May 1998.

Figure 11.—A North Pacific right whale awaiting flensing at an Alaska whaling station, circa 1930. University of Washington Special Collections, Lagen Collection, negative UW17495.

Table 6.—Reported takes of North Pacific right whales after 1910 (Anonymous, 1991a).

Years	Takes	North Pacific region	Source
1910–30	123	Total (western and eastern)	Scarff, 1986
1917–37	24	Alaska, British Columbia	Brueggeman et al., 1986
1931–82	77	Western	Scarff, 1986

Historic Exploitation Patterns

North Pacific

In the North Pacific, Japan hunted right whales from as early as the 1570's (Omura, 1986) through 1964 (Du Pasquier, 1986). By the end of the 19th century, North Pacific right whales were rare (Fig. 11). Most of this depletion was due to pelagic whaling in the Sea of Japan (Omura, 1986), in the Okhotsk Sea (Kugler, 1986), and in the central and eastern North Pacific (Kugler, 1986) starting in the 1820's. The number of right whales reported taken after 1909 are summarized in Table 6. Right whales have been legally protected in the North Pacific and throughout their entire range since 1935 (Brownell[25]). However, recent reports indicate that Soviet whalers continued harvesting right whales until 1971 (Zemsky et al., 1995; Tormosov et al., 1998).

North Atlantic

Right whales were the first whale species to be exploited for commercial purposes. Their large size, slow, and fairly predictable movements, coastal distribution, and the fact that they floated when dead, made them the prime target of early European whalers (Cherfas, 1989). Basque whalers began harvesting the first eastern North Atlantic right whales in the Bay of Biscay (Fig. 7), off the Spanish coast, around the 1100's (Aguilar, 1986). When right whales in the Bay of Biscay became rare, the Basque whalers moved their operation to the Labrador and Newfoundland coasts where they took an estimated 25,000 to 40,000 right whales in an 80-year period (Aguilar, 1986). By the late 1600's, western North Atlantic right whales were severely depleted, causing the era of Basque whaling to come to a close (Barkham, 1984).

In the 1700's, English and Dutch whalers began commercial hunts for right whales off Spitsbergen, although by this time it appears that the whales were already scarce. In the late 1700's, the French expanded their search for right whales to the South Atlantic, eventually reaching Australia, New Zealand, and Chile (see below) (Cherfas, 1989).

Right whales were also hunted off the eastern United States from the 1600's to the early 1900's. The waters off eastern Canada, Cape Cod, Nantucket, Long Island, New Jersey, Delaware Bay, Georgia, and Florida all served as whaling grounds during this period

[25] Brownell, R. L. 1998. NMFS Southwest Fisheries Science Center, La Jolla, CA 92038. Personal commun.

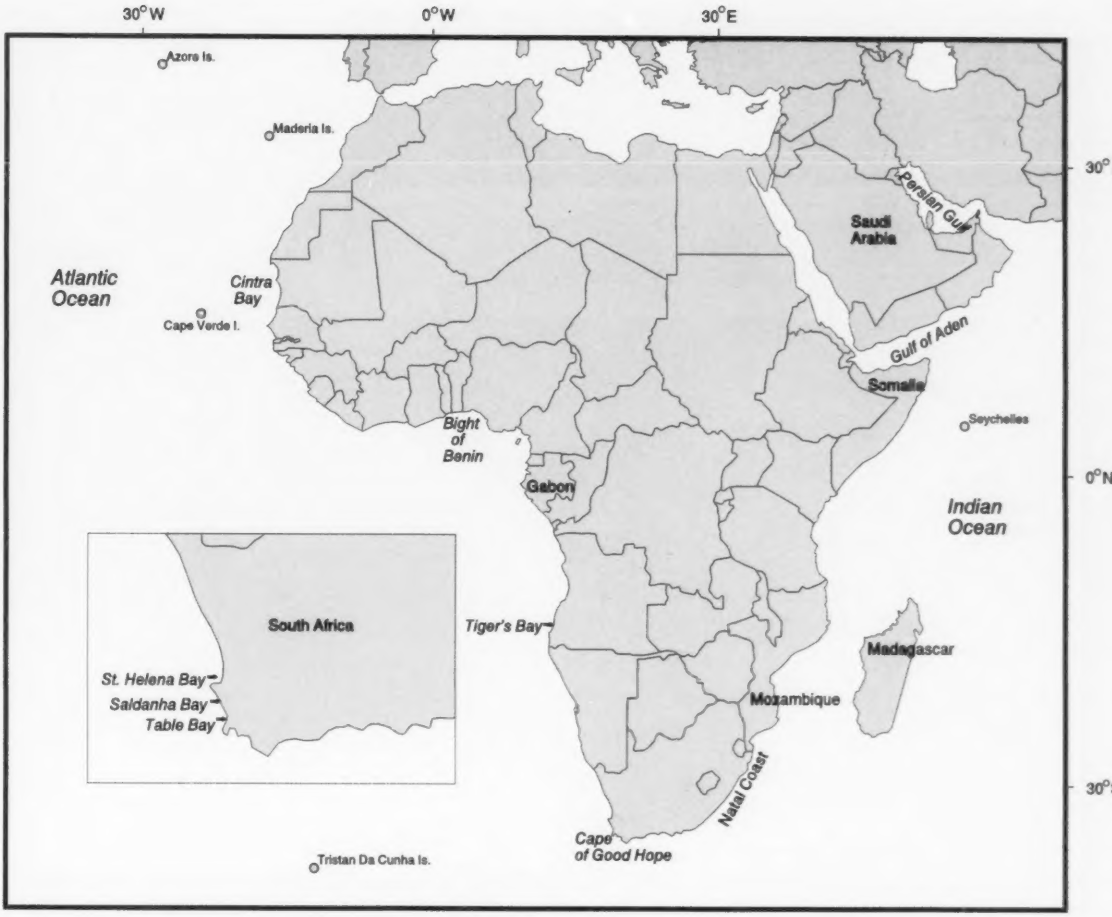


Figure 12.—Eastern South Atlantic/Western Indian Ocean region.

(Fig. 6) (Schevill and Moore, 1983; Reeves and Mitchell, 1986). Since catch records from this region are based on the quantity of commercial product sold rather than quantity of animals taken, no preexploitation trends or estimates of the population can be ascertained (Reeves and Mitchell, 1986). All stocks in the North Atlantic were severely depleted by the late 1700's (Kraus et al., 1988). However, between 1900 and 1982, a total of 138 or 141 right whales were taken from the eastern North Atlantic (Brown, 1986). The most intense episode of whaling in this region occurred off the Shetlands, Hebrides, and Ireland (Fig. 7) in the years 1906–10 (Brown, 1986). In addition, shore whaling along the U.S. east coast continued until 1924, with reported catches in the hundreds (Reeves and Mitchell, 1988).

Southern Hemisphere

When right whale numbers in the North Atlantic began to decline in the late 1700's, the French (and later the British) expanded their whaling operations to the South Atlantic (du Pasquier, 1986). From 1784 to 1794, under the command of mostly Nantucket whalemen, the coasts of Africa (e.g. Tiger's Bay, Saldanha Bay, Saint-Helena Bay, Table Bay), the Brazil Banks, and Falkland Islands were the focus of whaling for the French (Fig. 12, 13). During this 10 year period approximately 1,405 right whales were taken (du Pasquier, 1986). At this same time, shore-based open-boat whaling began along the South African coast and lasted until 1912. These South African operations took approximately 1,580 right whales (Best and Ross, 1986). By the 1830's, the right whale, which had been the principal target of all South African whaling, was in noticeable decline (Best, 1970).

From 1817 through 1837, the French increased whaling efforts on the Brazil Banks east of South America where, by 1837, they had taken an estimated 3,600 right whales (du Pasquier, 1986). After

Figure 13.—Western South Atlantic/Eastern South Pacific region.

1831, when the number of right whales being caught declined in this area, whaling effort was expanded to Tristan da Cunha (Fig. 12), the African coast, and eventually west into the Pacific via Cape Horn.

By 1837, the French were whaling off the Chilean coast, where roughly 2,400 right whales were taken by the French until the year 1868 (du Pasquier, 1986). These catches included a high number of mature females with some calves and juveniles, with potentially damaging consequences to the right whale's reproductive potential in these areas (Best and Ross, 1986; du Pasquier, 1986).

Whaling for right whales also occurred in the southern Pacific Ocean off Australia and New Zealand (Bannister, 1986a, b; Dawbin, 1986; du Pasquier, 1986). Local bay whaling, or shore-based operations off the southern coasts of western Australia, first began in the 1800's for both right and humpback whales (Bannister, 1986a). Pelagic whaling (conducted by the Australians, British, and French) began in these waters during the mid to late 1830's and lasted until the late 1880's. After 1835, some French whaling vessels moved from the South Atlantic via the Cape of Good Hope and began whaling (using both pelagic and bay operations), operating mostly off New Zealand in the bays off Banks Peninsula, and in the South Indian Ocean, the bays of southern Australia, Tasmania, and the Chatham Islands (Fig. 14) (du Pasquier, 1986). Dawbin (1986) estimated from whaling logbooks and station records that at least 26,000 right whales were caught in southwest Pacific waters between 1827 and 1899 by both bay and pelagic whalers. Dawbin (1986) also surmised that a major portion of world right whale catches (one-third or more) from 1835 to 1846 were taken off southeastern Australia and New Zealand. This large catch, however, was followed by a rapid decline in the number of whales caught: 300 whales after 1846, and less than 50 whales after 1862 (Dawbin, 1986). In waters off southwestern Australia, a similar pattern of rapid decline occurred

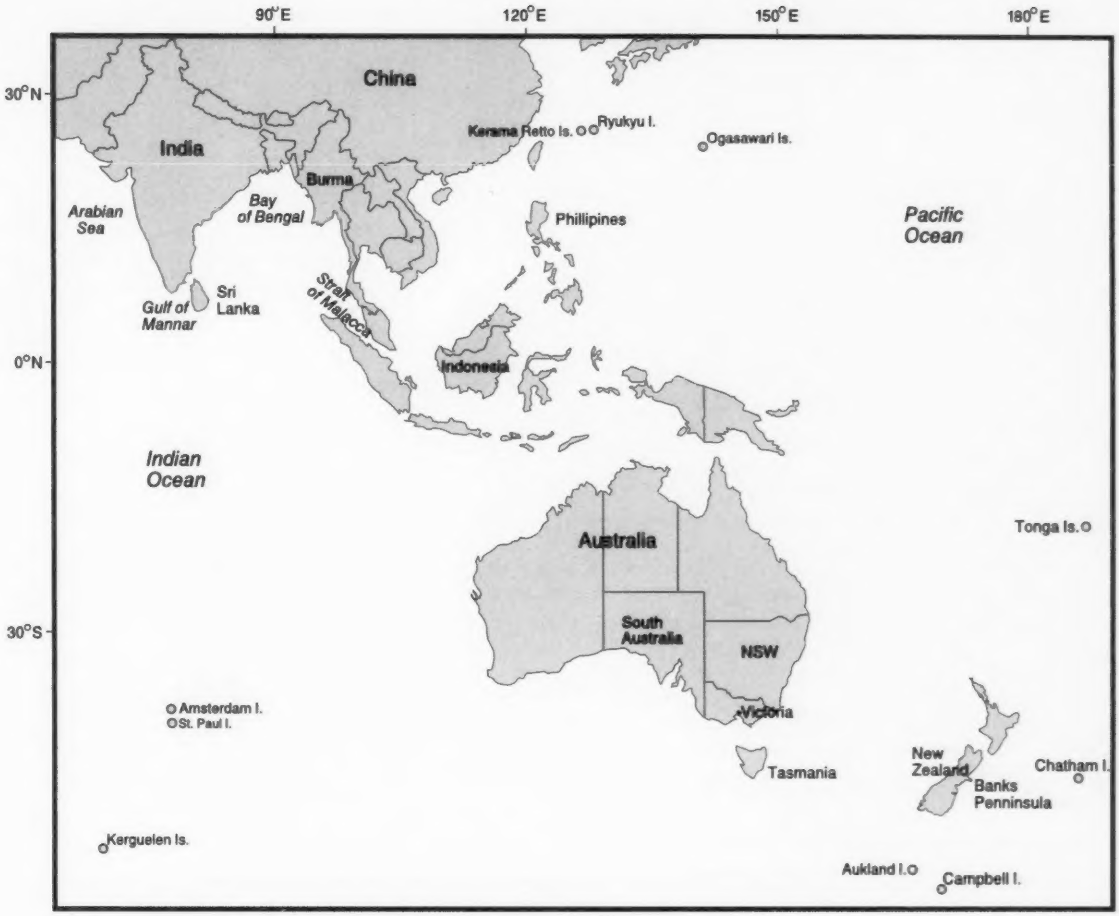


Figure 14.—Eastern Indian Ocean/Western South Pacific region.

after a peak pelagic catch between 1838 and 1849 (Bannister, 1986b). In the South Pacific, as in the South Atlantic, the high percentage of female and immature whales in the catches (particularly in the bay-type operations) most likely had long-term effects on the reproductive success of right whales in these areas.

Current Exploitation

Currently, the IWC has assigned "Protected Stock" status to all stocks of right whales (IWC, 1995b). The catch quota on these whales is therefore set at zero for all signatory nations of the IWC.

Recently revealed Soviet catch records show that at least 3,368 southern right whales were harvested between 1951 and 1971 (Tormosov et al., 1998). These records are still incomplete, and no information on the exact geographic distribution of these catches has been reported although they are known to have occurred in both the North Pacific and the Southern Hemisphere (Zemsky et al., 1995).

Life History and Ecology

Feeding

The feeding season for right whales occurs in the spring and fall in both hemispheres, where they take advantage of large concentrations of zooplankton, primarily copepods, found in temperate to subarctic waters. Oceanographic and bathymetric features, such as relatively cool water temperatures and depths of 100–200 m adjacent to steeply sloping bottom topography, also seem to correspond to the utilization of certain areas for feeding (Winn et al., 1986).

In the North Pacific, right whales feed primarily on copepods of the genus *Neocalanus*, but they are also known to prey on a variety of zooplankton species, namely *Calanus marshallae*, *Euphausia pacifica*, and *Metridia* spp. (Omura, 1986). In the North Atlantic, *Calanus marshallae* spp. are the primary copepod prey (Kraus et al., 1988; Wishner et al., 1988; Murison and

Gaskin, 1989; Mayo and Marx, 1990), with *Centropages, Pseudocalanus* (Mayo and Marx, 1990), juvenile euphausiids of the genus *Thysanoëssa* and *Meganyctiphanes* also found in the diet (Clapham, 1999). Southern right whales also feed upon calanoid copepods, as well as on the pelagic post-larval stage of *Munida gregaria* (Matthews, 1932), and krill, *Euphausia superba* (Braham[3]).

Interspecific competition may limit the prey available to northern right whales (Anonymous, 1991a; Kraus et al., 1988). In both the eastern North Pacific and the North Atlantic, sei whale, *Balaenoptera borealis*, distribution is sympatric with northern right whale distribution. Because both species feed on small zooplankton species, there may be some competition (Mitchell, 1975a). It is possible that some fish species also compete with right whales in the Gulf of Maine, including sandlance, *Ammodytes* spp.; herring, *Clupea* spp.; Atlantic mackerel, *Scomber scombrus*; river herrings (shad, bluebacks, *Alosa* spp.); menhaden, *Brevoortia tyrannus*; and basking sharks, *Cetorhinus maximus*. These fish share the northern right whale's summer distribution and to some extent utilize the same zooplankton prey species (Anonymous, 1991a).

Reproduction

Most right whale stocks utilize shallow, coastal waters for nursery areas. Calving takes place between December and April in the North Atlantic (Kraus et al.[26]) and between late July and late October in the Southern Hemisphere (Best, 1994a). Throughout their range, females give birth to their first calf around 9 years of age (Hamilton et al.[27]; Cooke et al.[28]; Best et al.[29]). Calves are born at 5.5–6.0 m in length (Best, 1994a). The calving interval for right whales is between 2 and 7 years, with means ranging from 3.12 (95% CI 3.05–3.17) to 3.6 years (95% CI [28]; Best et al.[29]; Burnell[30]). In the North Atlantic, there was a significant increase ($P<0.001$) in the calving interval from 1985 to 1997 from 3.33 to 5.36 years (Kraus et al.[26]). Gestation lasts from 357 to 396 days in southern right whales (Best, 1994a), and weaning seems to be variable, reported as 8–17 months in northern right whales (Hamilton and Marx, 1995).

Virtually nothing is known about reproductive parameters in North Pacific right whales. There have been no recently confirmed sightings of young right whales in the North Pacific; only the report of a relatively small whale in 1996 (Goddard and Rugh, 1998). In the western North Atlantic, a mean of 11.2 (SE = 0.90) calves were born annually between 1980 and 1992 (Waring et al., 1998). The 1986 Right Whale Working Group (IWC, 1986a) provided a mean gross annual reproductive rate (GARR) to aid in the calculation of population growth rates (Brownell et al., 1986). This GARR represents the number of young of the year as a proportion of the entire population. For the North Atlantic, the GARR has been estimated at 0.070 to 0.092 calves per year (Brownell, 1986; Knowlton and Kraus[31]).

Natural Mortality

Little is known about natural mortality in this species. North Atlantic right whales bearing scars from killer whale, *Orcinus orca*, attacks have been photographed (Kraus, 1990), but the number of whales killed by this predator is unknown. Using photo-identification data from the western North Atlantic stock, Kraus (1990) calculated an average natural mortality rate of 17% per year in first-year right whales, while second- through fourth-year whales had an average natural mortality rate of 3% per year.

An "unusual mortality" event occurred in the western North Atlantic from January through March 1996, when there were eight reported right whale mortalities off the southeastern United States. Of these, only four were examined for cause of death, with three showing signs of human interaction (e.g. vessel collision and fisheries entanglement). Waring et al. (1998) cautioned against making any assumptions about this event being related to increased mortality in the population as a whole. However, there were at least three calf mortalities in 1996 which may indicate fairly high neonatal mortality (Wang[32])

Human-related Mortality

As noted above, the primary factor influencing the recovery of the right whale involves their occurrence in coastal habitats. This aspect of their distribution places them in direct contact with shipping traffic, fishery operations, coastal oil and gas development, and other human activities. The five factors influencing the recovery of North Pacific and western North Atlantic right whale stocks are summarized in Table 7.

Fisheries Interactions

The magnitude and nature of fisheries interactions on right whales is not completely known. Apparently, some whales survive an entanglement, but in some cases, injuries not initially lethal may result in gradual weakening of entangled individuals, making them more vulnerable to some other direct causes of mortality (Kenney and Kraus, 1993).

Data are scant for North Pacific right whales: two fishery-related mortalities have been reported from Russian waters (Anonymous, 1991a; Kornev, 1994).

[26] Kraus, S. D., R. D. Kenney, A. R. Knowlton, and J. N. Ciano. 1993. Endangered right whales of the southwestern North Atlantic. Rep. to Minerals Manage. Serv., 1110 Herndon Pkwy., Herndon, VA 22070. Contr. 14-35-0001-30486.

[27] Hamilton, P. K., A. R. Knowlton, M. K. Marx, and S. D. Kraus. 1998. Age structure and longevity in North Atlantic right whales (*Eubalaena glacialis*). Rep. submitted to Mar. Ecol. Prog. Ser.

[28] Cooke, J. G., R. Payne, and V. Rowntree. 1998. Updated estimates of demographic parameters for the southern right whales (*Eubalaena australis*) observed off Peninsula Valdes, Argentina. Unpubl. doc. SC/M98/RW12 submitted to the IWC Workshop on the Comprehensive Assessment of Right Whales, Cape Town, South Africa, May 1998.

[29] Best, P. B., A. Branadao, and D. Butterworth. 1998. Demographic parameters of southern right whales off South Africa. Unpubl. doc. SC/M98/RW16 submitted to the IWC Workshop on the Comprehensive Assessment of Right Whales, Cape Town, South Africa, May 1998.

[30] Burnell, S. R. 1998. Aspects of the reproductive biology and behavioral ecology of right whales off Australia. Unpubl. doc. SC/M98/RW19 submitted to the IWC Workshop on the Comprehensive Assessment of Right Whales, Cape Town, South Africa, May 1998.

[31] Knowlton, A. R., and S. Kraus. 1989. Calving intervals, rates and success in North Atlantic right whales (Abstr.) *In* Proceedings of the eighth biennial conference on the biology of marine mammals. Soc. Mar. Mammal., Lawrence, Kan.

[32] Wang, K. 1998. Fishery biologist, NMFS Southeast Region, Protected Resources Division, 9721 Executive Center Drive N., St. Petersburg, FL 33702.

Table 7.—Factors possibly influencing the recovery of right whale stocks under the ESA (1973) § 4 (a)(1),1992 Amend. (eastern North Atlantic data is not available).

Factor	North Pacific	Western North Atlantic	Southern Hemisphere
1. Present or threatened destruction or modification of habitat	Offshore oil and gas development (e.g. noise disturbance, oil spills)	Offshore oil and gas development; pollution; channel dredging	Offshore oil and gas development; pollution; channel dredging
2. Overutilization for commercial, recreational, scientific, or educational purposes	Unknown	Whale watching and scientific research vessel traffic	Whale watching vessel traffic
3. Disease or predation	Unknown	Unknown	Unknown
4. Inadequacy of existing regulatory mechanisms	Unknown	Current vessel traffic and fisheries regulations	Unknown
5. Other natural or man-made factors	Entanglement in fishing gear (e.g. drift gillnets)	Vessel collisions; entanglement in fishing gear (e.g. gillnets, lobster pots, seines, weirs)	Vessel collisions

In the western North Atlantic, an estimated 57% of right whales bear scars and injuries indicative of fishing gear entanglement (Kraus, 1990). Gillnets, lobster pots, seines, and fish weirs are the primary gear types that entangle right whales (Anonymous, 1991a; Anonymous[33]). Entanglement in fixed gear was estimated to account for 7% of the known mortality in right whales in the western North Atlantic from 1970 through early 1993 (Kenney and Kraus, 1993). Fisheries monitored by the NMFS from 1991 through 1995 had a mean annual mortality rate of 0.4 (CV = 0.33) right whales (Waring et al., 1998). However, a review of sighting data outside the observed fisheries (from records maintained by the New England Aquarium and the NMFS Northeast Regional Office) for the years 1991 through parts of 1996, indicated an estimated annual mortality rate (due to fisheries interactions) of 1.1 right whales (Waring et al., 1998). These rates are in contrast to the IWC conclusion in 1996 that approximately one right whale dies per year worldwide as a result of fishing gear entanglement. In response to this high level of mortality (relative to the current population level), Take Reduction Teams have been established. These teams develop take reduction plans which include measures to reduce incidental take of marine mammals in North Atlantic fisheries to below the current calculated removal level (Anonymous, 1997). In the 1996 plan, the Atlantic Offshore Cetacean Take Team recommended prohibiting pair trawl, driftnet, and longline fisheries from operating in designated critical right whale habitat (i.e. Cape Cod Bay, the Great South Channel, and southeast U.S. calving grounds) and during periods of peak right whale occurrence (Anonymous, 1997). In addition, the Atlantic Large Whale Take Reduction Team recommended gear modifications to gillnets and lobster pot lines, as well as time-area fishing closures in known right whale habitat (Anonymous, 1997). As a result of stranding and entanglement records of large whales from 1990 to 1994, the NMFS changed the classification of the Gulf of Maine and U.S. Atlantic lobster pot fisheries from Category III to Category I.[34]

Vessel Collisions

The greatest known cause of mortality among right whales in the North Atlantic is collision with ships. Out of 27 documented mortalities in the North Atlantic from 1970 through 1991, 22% were caused by ship propellers severing the tail stock, spine, or causing mortal wounds to the head region (Anonymous, 1991a). From 1991 through the beginning of 1993, an additional three mortalities were reported in the North Atlantic as a result of collisions with vessels (Kenney and Kraus, 1993). From 1991 to 1996, the reported average mortality and serious injury rate due to vessel collisions was three per year (Waring et al., 1998). The low incidence (7%) of photographically identified whales showing scars and wounds from ship propellers compared to the high rate of ship propeller wounds in stranded animals indicates that most interactions between ship and whale are fatal to the whale (Kraus, 1990). Increased monitoring and warning of vessels operating in the presence of right whales, particularly in areas of high calf density, such as in southeastern U.S. coastal waters, may be important components in efforts to reduce this form of mortality (Anonymous, 1997). Such monitoring has begun in the western North Atlantic, where a real-time aerial warning system, educational pamphlets, and delineation of critical right whale habitat on nautical charts are all part of the effort to reduce ship strikes (Slay et al.[35]). Vessel-related mortality rates for stocks in the North Pacific are unknown.

In the Southern Hemisphere, three fatal ship strikes were reported from Brazil from 1989 to 1993, and 10 fatal ship strikes were reported from South Africa from 1983 to 1997 at the IWC Comprehensive Assessment Workshop[14]. The Workshop concluded that

[33] Anonymous. 1992. Proposed regime to govern interactions between marine mammals and commercial fishing operations: draft legislative environmental impact statement. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Off. Protected Resour., Silver Spring, MD 20910.

[34] A Category III fishery classification is assigned to those fisheries in which it is highly unlikely that marine mammals will be incidentally taken during a 20-day period, while a Category I fishery classification is assigned to a fishery that has documented frequent incidental take and in which it is highly likely that more than one marine mammal will be incidentally taken by a randomly selected vessel of the fishery during a 20-day period. See also Federal Register (1997), Taking of marine mammals incidental to commercial fishing operations; Atlantic Large Whale Take Reduction Plan regulations. Fed. Regist. 62(140), 50 CFR pt. 229.

[35] Slay, C. K., S. D. Kraus, P. K. Hamilton, A. R. Knowlton, and L. A. Conger. 1998. Early warning system 1994-1997. Aerial surveys to reduce ship/whale collisions in the North Atlantic right whale calving ground. Unpubl. doc. SC/M98/RW6 submitted to the IWC Workshop on the Comprehensive Assessment of Right Whales, Cape Town, South Africa, May 1998.

many of the problems faced by right whales in the North Atlantic with regard to ship traffic may also be faced by right whales in the Southern Hemisphere. Therefore, recommendations were made regarding the control of shipping activity in areas where the density of right whales is known or critical right whale habitat has been designated (IWC[14]).

Habitat Destruction

A continued threat to the coastal habitat of the right whale in both the North Atlantic and North Pacific is the undersea exploration and development of techniques for mining mineral deposits, as well as the dredging of major shipping channels. Offshore oil and gas activities have been proposed off the U.S. middle and south Atlantic coasts and are currently being conducted in the Bering Sea and in eastern North Pacific waters (Anonymous, 1991a). Right whales also frequent coastal waters where dredging and its associated disposal operations occur on a regular basis, such as along the southeastern U.S. coast. It is unknown to what extent these activities affect right whales. It appears that their level of sensitivity to noise disturbance and vessel activity is related to the behavior and activity in which they are engaged at the time (Watkins, 1986; Anonymous, 1991a), but further study is necessary.

Pollution

Relatively low levels of organochlorine contaminants have been found in right whale blubber, most notably PCB and DDT (Woodley et al., 1991). Contaminant levels are low because baleen whales feed lower on the food web than odontocetes and follow seasonal migration patterns that decrease their exposure to localized contaminants. The levels at which these contaminants occur in baleen whales are likely too low to be linked to any direct mortality or impaired reproductive functioning, and therefore they are not considered primary factors in slowing the recovery of any stocks of large whales (O'Shea and Brownell, 1994). However, some contaminants affect phytoplankton and zooplankton density and distribution, and therefore the energetics and distribution of right whales may be affected (Anonymous, 1991a).

Whale Watching and Small-boat Regulations

Concern has been raised over the impacts of whale-watching activities and scientific field research on right whale aggregations, particularly in the western North Atlantic (i.e. Cape Cod Bay and lower Bay of Fundy) (Anonymous, 1991a). These activities, like the industrial shipping activities discussed above, have the potential to disturb right whales or disrupt their activities. The effect of these human activities on right whales is not known. Nonetheless, to diminish the likelihood of vessel disturbance and to reduce the risk of a vessel striking a whale, the NMFS issued regulations in 1997 that prohibit the approach of any vessel, not in possession of a special NMFS permit, within 500 yards of a right whale in waters off the U.S. east coast (Anonymous, 1987; Federal Register[36]).

Classification Status

The northern right whale was listed as endangered under the ESA in 1973 and designated depleted under the MMPA. This status applies to all stocks in U.S. waters (Anonymous, 1994b). Worldwide, all right whale stocks are designated as "Protected Stock" by the IWC. Under this designation, the IWC recognizes that all stocks of right whales are 10% or more below their MSY level (IWC, 1995b).

Threats to right whales continue to exist (Table 7); however, there is incomplete information regarding potential threats in the eastern North Atlantic. Any reevaluation of northern and southern right whale status awaits collection of more reliable information on abundance, distribution, and threats from human activities in the North Pacific, eastern North Atlantic, and Southern Hemisphere, as well as the development of objective delisting criteria.

The eastern North Pacific right whale stock clearly remains severely depleted. Virtually nothing is known about its current size, trends in abundance, distribution, or migration patterns. The size of this stock is thought to be very small, but there are no reliable estimates of abundance. The classification of this stock should not change at this time and is not likely to change in the foreseeable future. Preliminary survey data from 1989, 1990, and 1992 in the western North Pacific yields a preliminary estimate of only a few hundred animals (Brownell[23]).

As noted above, the size of the western North Atlantic stock is estimated at about 300 individuals. This number has not increased significantly since the species received international protection in 1935. It is generally agreed that the current rate of population increase is low, about 2.0–2.5% annually (IWC[14]). In addition, the western North Atlantic population has exhibited annual oscillation in recruitment, a near-failure of calf production from 1993 to 1995, and a significant increase in calving intervals between 1985 and 1997 (IWC[14]). Also, mortality and serious injury from human activities continue to slow recovery. In this regard, the potential biological removal (PBR) level[37] for the North Atlantic right whale, estimated at 0.4 whales per year (Waring et al., 1998), has been exceeded for each of the last 5 years. From 1991 to September 1996 the estimated average annual human-induced mortality and serious injury rate (both from fishery and nonfishery related activities) was three whales (Waring et al., 1998).

The northern right whale recovery plan (Anonymous, 1991a) stated that recovery was likely to be slow and estimated that even under the best conditions, it would likely take more than 100 years for the species to recover to preexploitation levels in both the Pacific and Atlantic Oceans. Therefore, with regard to the western North Atlantic stock, the plan's interim goal was to outline a strategy for changing the sta-

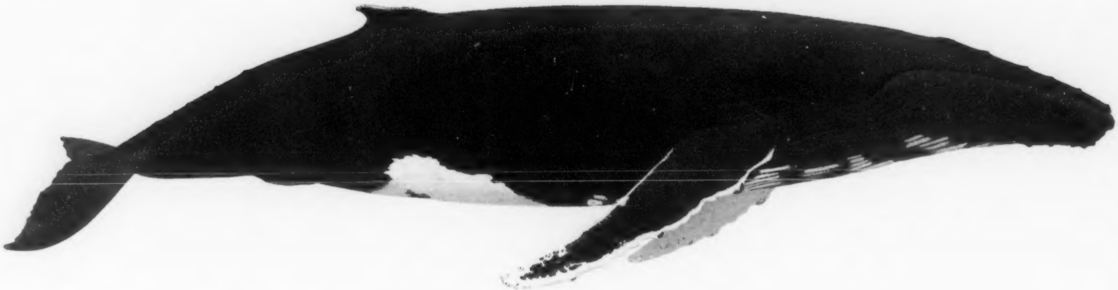
[36] Federal Register. 1996. Regulations governing the taking and importing of marine mammals. Fed. Regist. 50 CFR pt. 216.

[37] Under the 1994 MMPA reauthorization, PBR is defined as the product of minimum population size (N_{min}), half the maximum productivity rate, and a specified "recovery" factor. For endangered species, the recovery factor is typically 0.1. And for cetaceans, the default maximum net productivity rate is 4%, if a current, statistically reliable maximum productivity rate is not available.

tus of the population from endangered to threatened. This strategy recommended that a classification change should only be considered after:

1) The size of the population recovered to a level of 6,000 individuals,
2) The population increased steadily over a period of 20 years or more at an average annual net recruitment rate of at least 2% per year, and
3) An effective program was in place to reduce human-related mortality and ensure that deterioration of essential habitat was not likely to occur, thereby allowing abundance to increase to the optimum sustainable population level.

New data on population size and trends in abundance have been collected since the 1991 recovery plan and should be used in revising Criteria 1 and 2. Criteria 3 should also be reevaluated, since programs are in place to facilitate the recovery of this population, but threats from human activities remain (Table 7). Given existing and continuing threats to northern right whales and little or no evidence of moving toward attaining population increase criteria, the endangered status of the western North Atlantic right whale stock should remain unchanged for the foreseeable future.



The Humpback Whale

Introduction

The humpback whale, *Megaptera novaeangliae* Borowski 1781, is a member of the Balaenopteridae family, a group of baleen whales commonly known as rorquals. The humpback whale is of medium size relative to the other large whales, reaching a length of 15 m and a weight of about 34 metric tons (t) at maturity. Humpback whales are characterized by wing-like pectoral flippers that are from one-fourth to one-third their total body length, heads covered in bumps known as tubercles, and tail flukes with individually identifiable trailing-edge patterns (Fig. 15). Like other balaenopterids, they have fringed baleen plates instead of teeth which allow for the filtering of small crustaceans and fish. Deep grooves on the ventral surface allow for throat expansion, increasing the volume of water that can be engulfed and then filtered through the baleen.

Humpback whales display a wide range of above-water behaviors, such as whole-body breaches, lob-tailing, and lunging. These behaviors are usually associated with breeding and feeding activities (Ward, 1995) (Fig. 16). These whales also have a distinctive and varied acoustic repertoire consisting of complex "songs" that may last several hours and contain phrases which are distinct between individuals and vary among geographic areas.

In general, most humpback whales spend the summer feeding in high-latitude waters and then migrate long distances into low-latitude tropical waters for the winter where they breed and calve. Calving takes place in shallow coastal waters along continental shelves and off some oceanic islands.

Distribution and Migration

Humpback whales inhabit all major ocean basins from the equator to subpolar latitudes (Fig. 17). They generally follow a predictable migratory pattern in both hemispheres, feeding during the summer in the higher near-polar latitudes and then during the winter migrating to the lower latitudes where calving and breeding takes place. Their migratory movements have been traced through recovery of Discovery tags[38] during commercial whaling operations. More recently, comparisons of photographs, songs, and genetic material between different geographical areas have led scientists toward a better understanding of the stock structure of these whales.

North Pacific

The IWC has designated one stock of humpback whales in the North Pacific Ocean (Donovan, 1991). These whales range widely across the entire North Pacific during the summer months—south to Point Conception, Calif., and north into the Bering Sea (Johnson and Wolman, 1984).

Recent, on-going photo-identification and genetic studies reveal what may be separate stocks of humpback whales within the North Pacific basin that are not apparent from any geographical separation. There are known calving and breeding grounds off Mexico, among the Hawaiian Islands, and off Japan. Known feeding grounds exist off California, Oregon, and Washington (CA/OR/WA), in the Bering Sea, along the Aleutian Islands, and in southeastern Alaska (Fig. 4). Barlow (1994b) lists four separate migratory stocks of humpback whales in the North Pacific based on current resightings, genetic analysis, and historical whaling records (Table 8).

Calambokidis et al. (1996) have shown through photographic mark-recapture analysis that the summer feeding aggregations off the western United

Table 8.—North Pacific humpback whale stocks.

Winter areas (breeding/calving)	Summer areas (feeding)	Source
Mexico (Mainland, Baja California, Gulf of California), Costa Rica	CA/OR/WA	Steiger et al., 1991; Barlow et al., 1997; Clapham et al., 1997
Offshore Mexico-Islas Revillagigedo	Unknown	Medrano-Gonzalez et al., 1995
Central North Pacific–Hawaii	Alaska–Prince William Sound to British Columbia	Baker et al., 1994; Barlow et al., 1997
Western North Pacific–Japan, Taiwan	Bering Sea, Aleutian Islands–west of Kodiak Archipelago	Darling et al., 1996

[38] Discovery tags were shot into individual whales during whaling operations. The tag was a steel rod 23 cm in length and 1.5 cm in diameter with a lead tip and was fired from a modified 12-gauge shotgun. Such marking began in 1949, although it was geographically limited to the Southern Hemisphere (until 1979) and North Pacific (until 1980) (Brown, 1981; Ivashin, 1983).

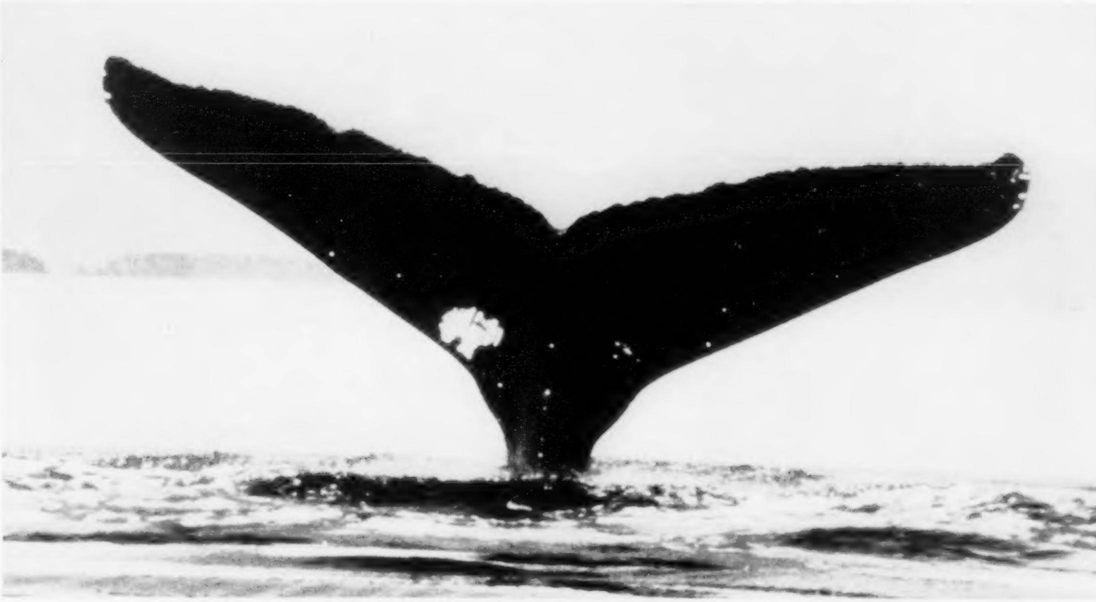


Figure 15.—The tail flukes of a humpback whale in southeast Alaska. The pattern of notches and scars along the trailing edge (top of the tail in this photograph) varies among individuals. J. Reinke, NMML Collection.

States (CA/OR/WA stock) may be a distinct population with only limited interchange between feeding areas in British Columbia and Alaska. British Columbia appears to serve as a geographical boundary between feeding populations (Calambokidis et al.[39]). In addition, genetic differences between California and Alaska feeding groups based on mitochondrial DNA and nuclear DNA analysis have been detected (Baker et al., 1990, 1993, 1994). The genetic exchange rate between these two feeding aggregations is estimated at less than one female per generation; however, the sample size used for this analysis was too small to make formal conclusions about the segregation between these two areas (Baker et al., 1994; Baker[40]). Baker[40] found fewer genetic differences between whales on the Mexico and Hawaii wintering grounds, which suggests a maternally directed fidelity to specific summering grounds. Genetic studies have also shown that the humpback whales which

Figure 16.—A humpback whale off Sunset Island, Alaska, breaks the water's surface. This strange image is the result of complete deflation of the throat pleats and the whale pushing water through its baleen and out the sides of its mouth. A. Wolman, NMML Collection.

[39] Calambokidis, J., G. H. Steiger , and J. R. Evenson. 1993. Photographic identification and abundance estimates of humpback and blue whales off California in 1991-92. Final contr. rep. 50ABNF100137 to NMFS Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038, 67 p.

[40] Baker, C. S. 1992. Genetic variability and stock identity of humpback whales, world-wide. Final contr. rep. to the IWC, Camb., U.K., 45 p.

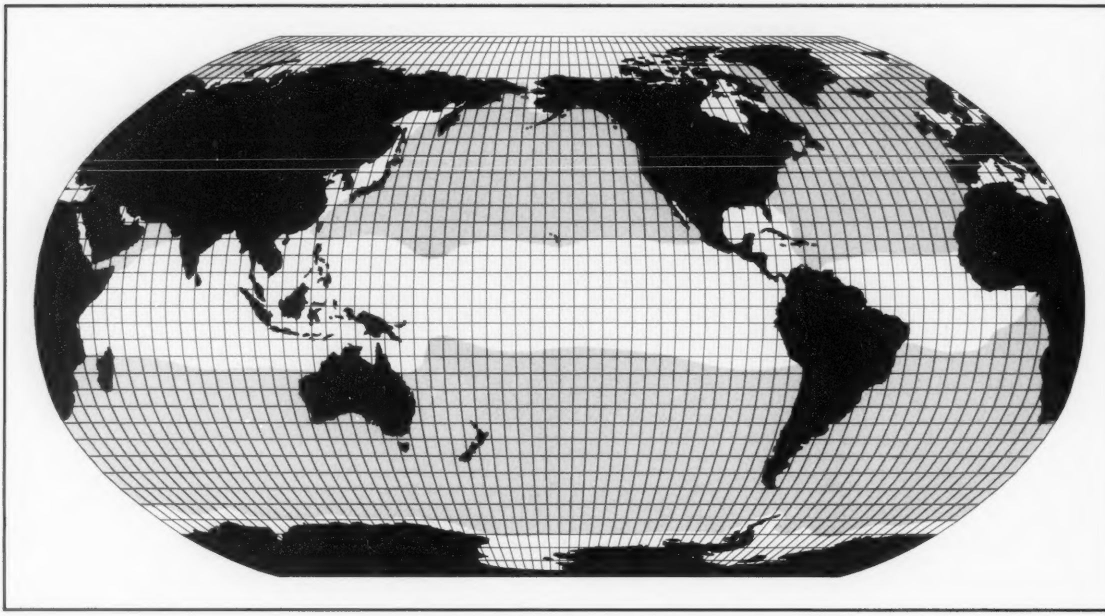


Figure 17.—Worldwide humpback whale distribution. Adapted from Johnson and Wolman (1984).

breed and calve off the Revillagigedo Islands, Mex., are significantly different from the humpback whales found along Baja California and coastal Mexico (Fig. 4)(Medrano-Gonzalez et al., 1995). Currently, the feeding area(s) of the whales wintering off the Revillagigedo Islands is unknown.

The central North Pacific migratory stock of humpback whales travels from Hawaiian wintering grounds to summering areas in southeast Alaska each year. In inside waters off southeastern Alaska (i.e. Glacier Bay and Frederick Sound), photo-identification studies appear to show that humpback whales utilize discrete, geographically isolated feeding areas which individual whales return to year after year (Straley[41]). There has been little documented exchange in individual animals between Prince William Sound and Kodiak Island areas, and between Kodiak Island and southeast Alaska feeding areas, suggesting that this type of movement occurs, but is reasonably uncommon (von Zeigesar et al., 1994; Perry et al., 1990; Waite et al.[42]).

The western North Pacific migratory stock of humpback whales is known to calve and breed off Japan during the winter and spring, but their feeding areas during the summer are still in question (Darling et al., 1996; Darling[43]). Darling and Mori (1993) and Miyashita et al. (1996) document the occurrence of these whales in shallow coastal waters (usually within 10 km of shore) around the Ogasawari (Bonin) Islands (lat. 24–26°N, long. 141°E) and Kerama Islands (lat. 26–27°N, long. 127°E) during winter (Fig. 5). Darling[43] and Darling et al. (1996) provide evidence of resightings between whales in Japanese waters and whales found in the Bering Sea, Aleutian Islands, Hawaiian Islands, and off British Columbia in the summer months.

North Atlantic

The IWC Scientific Committee recognizes one stock of humpback whales in the North Atlantic Ocean (Donovan, 1991). However, historical whaling documents and recent research in the western North Atlantic have revealed distinct areas of seasonal concentration for the eastern and western halves of this ocean basin (Johnson and Wolman, 1984). From early 1992 to 1995, a large-scale ocean-wide study of humpback whales in the North Atlantic, called the Years of the North Atlantic Humpback project (YoNAH) (Allen et al.[44]), was conducted. Photo-identifications and genetic samples from this study are cur-

[41] Straley, J. M. 1994.Seasonal characterisitics of humpback whales (*Megaptera novaeangliae*) in southeastern Alaska. M.S. thesis, Univ. Alaska, Fairbanks, 121 p.

[42] Citation updated in proof: see Waite et al., 1998 in literature cited.

[43] Darling, J. D. 1991. Humpback whales in Japanese waters, Ogasawara and Okinawa: Fluke identification catalog 1987-1990. Final contr. rep., World Wide Fund for Nature, Japan, 22 p.

[44] Allen, J., P. Clapham, P. Hammond, S. Katona, F. Larsen, J. Lien, D. Mattila, N. Øien, P. Palsbøll, J. Sigurjonsson, and T. Smith. 1993. Years of the North Atlantic Humpback (YoNAH): progress report. Int. Whal. Comm. unpubl. doc. SC/45/NA6.

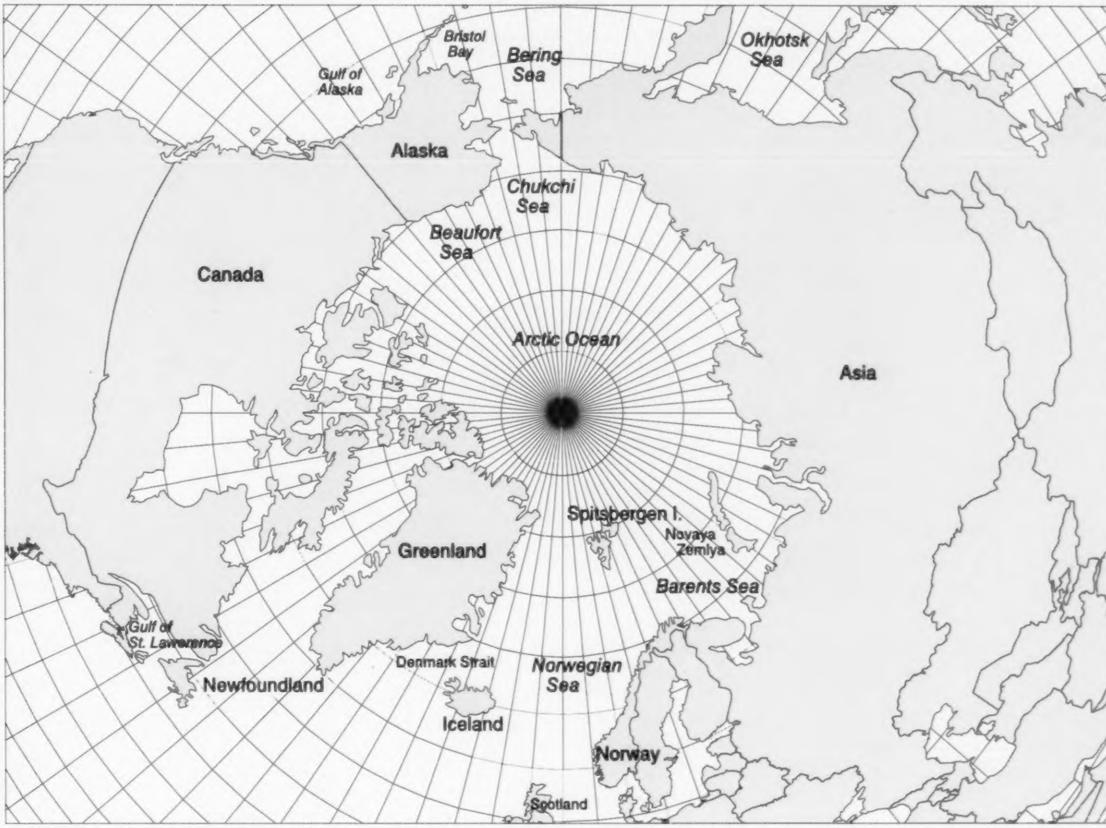


Figure 18.—Arctic region.

rently being analyzed in order to better determine the current population status and genetic relationships of North Atlantic humpback whales.

In the eastern North Atlantic, humpback whales are found in the summer off west and southwest Iceland; Scotland; Spitsbergen, Norway; and Novaya Zemlya in the Barents Sea (Fig. 18) (Sigurjónsson and Gunnlaugsson, 1990). In winter, the only documented concentration of humpback whales in the eastern North Atlantic is found off the Cape Verde Islands off western Africa (Fig. 7) (Kellogg, 1929).

In the western North Atlantic, the whales are found in five separate feeding aggregations between lat. 42°N and 78°N (Fig. 6)(Katona and Beard, 1990; Johnson and Wolman, 1984):

1) Iceland-Denmark Strait,
2) Southwest Greenland,
3) Southern Labrador and east of Newfoundland,
4) Gulf of St. Lawrence, and
5) Gulf of Maine/Nova Scotia region.

During summer, humpback whale distribution and shifts in distribution on New England feeding grounds have been correlated with the abundance and distribution of the whale's principal prey species (e.g. herring and sandlance) (Payne et al., 1986a, b; Fogarty et al., 1991; Weinrich et al., 1997). Recent photo-identification research indicates that the majority of whales from all five of these feeding areas migrate to Caribbean waters during winter for breeding and calving (Matilla et al., 1994). Approximately 85% of the humpback whales migrating between higher latitudes on the western side of the North Atlantic to lower latitudes can be found in winter on Silver and Navidad Banks off the northern coast of the Dominican Republic. The remainder of the whales, with resightings from the higher latitudes during summer, are found in the eastern part of Samana Bay, Dominican Republic (Mattila et al., 1994), the northwest coast of Puerto Rico, the Virgin Islands, and along the eastern Antilles south to Venezuela (Fig. 13)(Katona and Beard, 1990). In addition, there are reports of humpback whales found during winter off Greenland, Norway, Newfoundland, in the southern Gulf of Maine, and Bermuda (Fig. 6, 7) (Katona et al., 1994).

These reports from higher latitudes during winter suggest that not all whales migrate each year, perhaps taking advantage of unusual prey occurrences or demonstrating year-round, regional site fidelity (Clapham et al., 1993).

In addition to photo-identification studies, genetic research into the influence of seasonal migration on the geographic distribution of mitochondrial DNA haplotypes revealed what appears to be a maternally directed site fidelity to specific feeding grounds (Baker et al., 1990), as in the North Pacific. However, resightings have shown that interbreeding could be occurring during winter, when whales that were segregated on the summer feeding grounds (Clapham et al., 1992; Katona, 1986) congregate in the tropical latitudes.

Northern Indian Ocean

The humpback whale population in the Arabian Sea (Fig. 14), unlike other populations, does not migrate to temperate waters as part of their annual cycle. Instead, they both feed and breed in tropical waters (Mikhaliev, 1997). However, little or no research has been conducted on this unique population, so information on their current abundance and trends does not exist.

Southern Hemisphere

The six baleen whale areas designated by the IWC (Donovan, 1991) for stock management purposes are also used to separate Southern Hemisphere humpback whale stocks (Fig. 9). These areas loosely correspond to known humpback whale wintering and summering areas from sighting and mark-recapture data (Mackintosh, 1942). In the austral winter, the whales are found along the tropical and western sides of each continent, along eastern coastlines, and around island groups. One such wintering area exists off Brazil on Abrolhos Bank (Siciliano, 1995). During the austral summer months, they are found in South Georgia, the South Shetlands, and along the west and east coasts of Africa, Australia, and South America (Dawbin, 1966). Most migratory paths for the southern humpback whales are unknown. Movements of humpback whales along the South African coasts from Antarctic summering grounds to wintering grounds have been summarized in Best et al. (1995). One path takes the whales from the Antarctic region, past western South Africa, to wintering grounds off Angola, the Congo, or Gabon. The other path takes them past eastern South Africa to wintering grounds off Mozambique (Fig. 19).

Japanese Sighting Vessel (JSV) and International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR) surveys of Antarctic waters from lat. 60°S to the pack-ice edge indicate that concentrations of humpback whales occur in Areas III and IV (at long. 10–30°E, 50–60°E, and 90–100°E) during the austral summer. These concentrations make up well-defined feeding areas spread over a wide range of latitudes in which the whales show little longitudinal dispersal during the entire summer season (Kasamatsu et al., 1996). These areas correspond with observed concentrations of humpback whales during the 1930's period of modern whaling operations.

Findlay et al. (1994) reviewed the distribution of humpback whales along the Mozambique coast (Area III) during late winter through early spring and found that high densities of humpback whales were recently found in the region between long. 33° and 35°E, south of lat. 24°S (between Maputo and Ponta Zavora), and north of lat. 18°S. Their distribution indicates a highly mobile population, with an extended northern range which is not suggested in the modern whaling records. The waters in which the whales were found are characterized by shallow banks and the strong offshore flow of the Mozambique Current. A suspected calving/nursery area exists on northern Solfala Bank (Fig. 19).

During the same months that humpback whales are found off Mozambique, areas of concentration are also found in the southern coastal waters of Madagascar (Area III) (Best et al., 1996). According to anecdotal evidence, these whales are widely dispersed and highly mobile like the whales along the African coast (see above). The catch data from 19th century American whaling logbooks indicated humpback whale concentrations off Madagascar in the southwest near Tulear, the northeast near Baie du Antongil, and scattered along the central west coast at around lat. 20°S during August and September (Fig. 19) (Townsend, 1935).

Off Western Australia (Area IV), there is a possible area of calving/breeding off Cape Leveque (approx. lat. 17°S, long. 123°E) (Jenner and Jenner, 1994). However, the migratory movements between Antarctic waters and Australia are still not certain, and further research, such as continued shore-based monitoring projects (Paterson, 1991; Bryden et al., 1990), is needed.

Current and Historical Abundance

North Pacific

Currently, there are no statistically reliable estimates of humpback whale population abundance for the entire North Pacific Ocean. Calambokidis et al.[45] used photo-identification methods to estimate approximately 6,000 humpback whales in the entire North Pacific; but, considering statistical biases and separate regional estimates, the true abundance is likely to be higher. The IWC does not recognize any total population estimates as statistically accurate at this time (IWC, 1995a).

The most recent population estimates for the western U.S. (CA/OR/WA stock) feeding groups and central North Pacific stock are summarized in Table 9. Sighting cruises during winter 1993 through winter 1995 encountered only 56 individuals in areas of the western North Pacific and eastern South China Sea (Miyashita et al., 1996). The most recent estimate for the western North Pacific is 394 (CV = 0.084) whales based on photo-identification methods applied to data collected between 1991 and 1993 (Calambokidis et al.[45]). In the central North Pacific, Calambokidis et

[45] Calambokidis, J., G. H. Steiger, J. M. Straley, T. Quinn, L. M. Herman, S. Cerchio, D. R. Salden, M. Yamaguchi, F. Sato, J. R. Urbán, J. Jacobsen, O. von Ziegesar, K. C. Balcomb, C. M. Gabriele, M. E. Dahlheim, N. Higashi, J. K. B. Ford, Y. Miyamura, P. L. de Guevara, S. A. Mizroch, L. Schlender, and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final contr. rep. conducted by Cascadia Research Collective under Contr. 50ABNF500113 for NMFS Southwest Fisheries Science Center, La Jolla, Calif., 72 p.

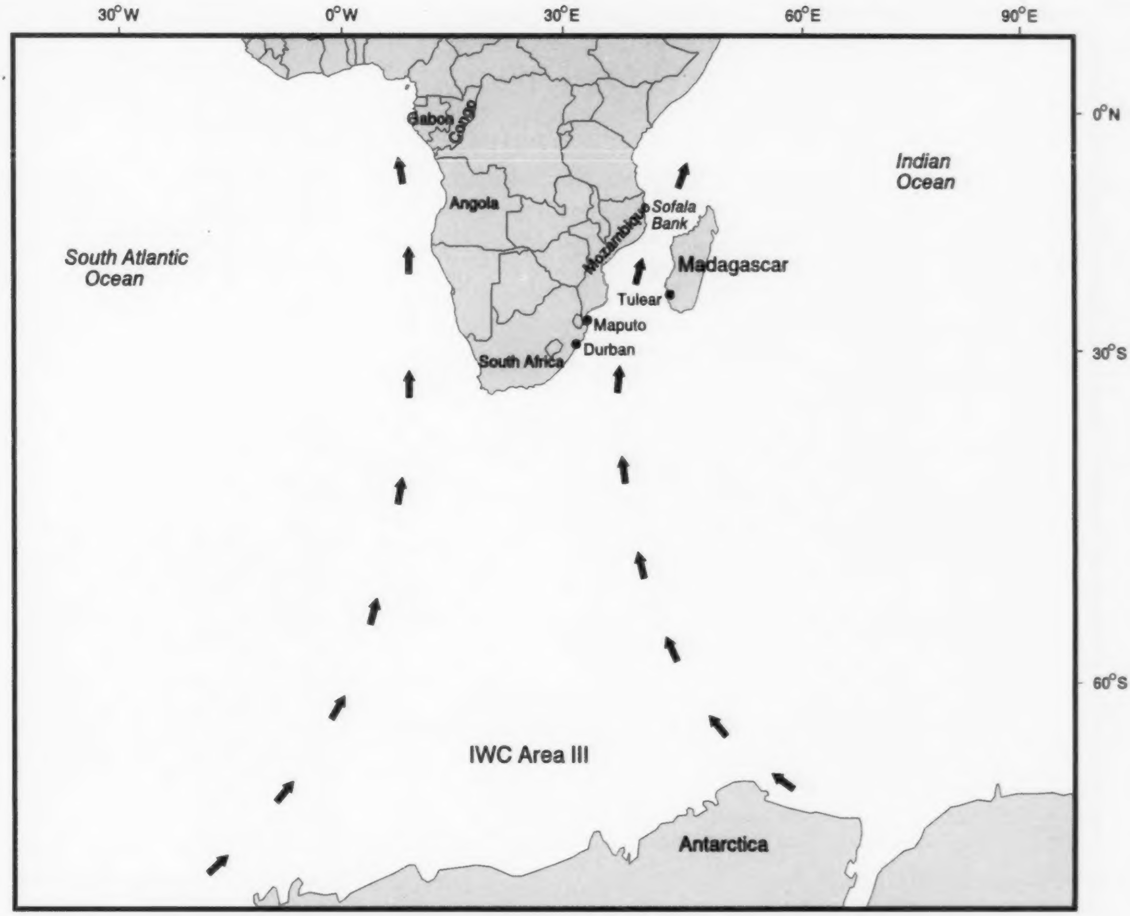


Figure 19.—Possible humpback whale migratory paths around southern Africa. Adapted from Best et al. (1995).

al.[45] used the same photo-identification methods applied to the western North Pacific whales and arrived at an estimate of 4,005 (CV = 0.095) in this region.

Before 1905, there were an estimated 15,000 humpback whales in the entire North Pacific (Rice, 1978a). After heavy exploitation, in 1966 this population was estimated at between 1,000 (Rice, 1978a) and 1,200 animals (Johnson and Wolman, 1984), although it is not clear whether these estimates represent the entire North Pacific or only the eastern North Pacific.

North Atlantic

Current estimates of North Atlantic humpback whale abundance are summarized in Table 9 by geographic area. In 1986, the IWC recognized a current "best" estimate of 5,561 (S.E. = 570, CV = 0.103) whales for the North Atlantic west of Iceland (IWC, 1986b). In contrast, Gunnlaugsson and Sigurjónsson (1990) estimated from sighting surveys west and southwest of Iceland, that less than 2,000 humpback whales inhabited those waters. Smith et al.[46] summarized some of the main findings from the YoNAH project, as well as other regionally based studies in the North Atlantic. For example, Palsbøll et al. (1997) used genetic data to estimate 7,698 humpback whales in the eastern North Atlantic. In the Smith et al.[46] summary, it is suggested that the new data generated by the YoNAH project may provide a solid base for a comprehensive assessment of the North Atlantic humpback whale's status by the IWC's Scientific Committee. In 1999, Smith et al.[11] arrived at an estimate of 10,600 (CV=0.067) humpback whales in the North Atlantic based on mark-recapture analysis of photographically identified animals.

An initial population estimate of 4,700 whales was derived from all whal-

[46] Smith, T. D., P. S. Hammond, N. Friday, and P. J. Clapham. 1997. Status of information on the North Atlantic humpback whale. Unpubl. doc. SC/49/NA8, submitted to Rep. Int. Whal. Comm., 4 p.

Table 9.—Abundance estimates for humpback whale stocks worldwide (N.e. = no published estimate).

Area	Population estimate	Coefficient of variation	95% confidence interval	Source[1]
North Pacific				
Total	6,000–8,000	N.e.	N.e.	Calambokidis et al.[45]
CA/OR/WA	2,250	N.e.	N.e.	Calambokidis et al.[45]
Central	1,407	N.e.	1,113–1,701	Baker and Herman, 1987; Anonymous, 1991b
Central	4,005	0.095	N.e.	Calambokidis et al.[45]
Western	394 (1991–1993)	0.084	N.e.	Calambokidis et al.[45]
North Atlantic				
Total	10,600	0.067	N.e.	Smith et al.[11]
Western (west of Iceland)	5,543 (1979–1990)	0.16	N.e.	Katona et al., 1994
Western	>2,000	N.e.	N.e.	Gunnlaugsson and Sigurjónsson, 1990
Cape Hatteras, North Carolina to Nova Scotia	294 (1978–1982)	0.45	N.e.	CeTAP[70]
Eastern	7,698			Palsbøll et al., 1997
Southern Hemisphere				
South of 60°S	4,660	0.193	N.e.	IWC, 1996a
Area II				
Abrolhos Bank, Brazil	1,556 (1989–1995)	N.e.	815–3,260	Bethlem et al.[48]
Abrolhos Bank, Brazil	1,100 (1995–1996)	N.e.	553–2,350	Bethlem et al.[48]
Area III				
South Africa (northward migration)	1,711	0.122–0.114	N.e.	Findlay and Best, 1996
Mozambique	1,954	0.38	N.e.	Findlay et al., 1994
Madagascar	2,532	0.27	N.e.	Best et al., 1996
Area IV				
Western Australia	3,878	N.e.	1,319–14,108	Jenner and Jenner,1994

[1] Source footnote numbers refer to text footnote numbers.

ing catches during the 1865 season from Davis Strait, Iceland, and south to the West Indies (Mitchell and Reeves, 1983). This is the only available historic abundance estimate from North Atlantic waters.

Southern Hemisphere

The IWC Scientific Committee has recognized data from IWC/IDCR and JSV surveys of the Antarctic Ocean as valid for population estimation south of lat. 60°S (IWC, 1996a; Butterworth et al.[47]). From these data, a total Southern Hemisphere population estimate of 19,851 humpback whales was calculated for the years 1978 through 1988. However, the Scientific Committee also recognizes this estimate as statistically unreliable (IWC, 1996a). Current estimates have been calculated for the concentrations of whales found in Areas III and IV— off South Africa, Mozambique, Madagascar, and Western Australia, respectively (Table 9). In the western South Atlantic, Bethlem et al.[48] estimated the number of humpback whales from Abrolhos Bank, off Bahia, Brazil, from 7 years of photo-identification studies (1989–96). Using the Bailey-modified Petersen estimation method, they estimated 1,556 individuals for the period 1989–94 and 1995 (95% CI 815–3260) and 1,100 individuals for the period 1995–96 (95% CI 553–2350) (Bethlem et al.[48]).

The initial preexploitation population size of the entire Southern Hemisphere has been estimated at 100,000 whales (Gambell, 1976). In western Australian waters, there were an estimated 800 whales at the end of 1962. By 1963, this estimate had dropped to only 568 (Bannister, 1964; Chittleborough, 1965).

Trends in Abundance

Comparison of current population estimates with analysis of historical whaling data from the U.S. west coast suggest that the California/Oregon/Washington stock of humpback whales may be below its preexploitation size (Clapham et al., 1997). More recent photographic capture-recapture data has led to higher estimates of abundance for the California/Oregon/Washington and central North Pacific humpback whale stocks (Table 9) (Calambokidis et al.[45]). However, this apparent increase should be viewed with caution, as it may only be an artifact of increased survey effort and shifts in the distribution of individual whales. Until more identification photos are collected and there are more complete demographic records from the entire North Pacific Ocean, there is no conclusive evidence as to whether these stocks are declining, increasing, or stationary.

At this time, there are insufficient data to produce reliable estimates of trends in the total North Atlantic humpback population (Waring et al., 1998). However, Katona and Beard (1990) and Sigurjónsson and Gunnlauggson (1990)

[47] Butterworth, D. S., D. L. Borchers, S. Chalis, and J. B. DeDecker. 1995. Estimation of abundance for Southern Hemisphere blue, fin, sei, humpback, sperm, killer, and pilot whales from the 1978/79 to 1990/91 IWC/IDCR sighting survey cruises, with extrapolations to the area south of 30° for the first five species based on Japanese scouting vessel data. Unpubl. doc. SC/46/SH24 submitted to Rep. Int. Whal. Comm., 54 p.

[48] Bethlem, C. B. P., P. G. Kinas, M. H. Engel, and A. C. S. Freitas. 1997. Abundance estimates of humpback whales wintering off Abrolhos Bank, Bahia, Brazil. Unpubl. doc. SC/49/SH31 submitted to Rep. Int. Whal. Comm., 6 p.

have suggested annual rates of increase from 9.0% to 14.8%, respectively. Barlow and Clapham (1997) used birth intervals to estimate a population growth rate of 6.5% (±1.2) for the Gulf of Maine humpback whale population. Estimated rates of net increase range from 3.9% to 11.8% for the western North Atlantic (Whitehead, 1982).

Trends in abundance in the Southern Hemisphere show an annual rate of increase in both western Australia (Bannister et al., 1991; Bannister, 1994) and southern Madagascar (Best et al., 1996). The western Australian population's recovery has been well documented, with a "best" estimate of annual rates of increase at 8.8% (±5.8%) for the years 1963–76, and at 10.9% (±3.0%) for the years 1963–91. Within Areas IV and V, annual rates of increase have been estimated at 8.9% and 56.6%, respectively, for the years 1988–96 (IWC, 1996a). The Southern Hemisphere Area IV stock has shown rates of increase between 10.3% and 13.1% since the mid 1960's (Chittleborough, 1965). All of these rates are considered unreliable pending greater accuracy in determining age at sexual maturity and exact calving intervals for this species.

Figure 20.—A humpback whale being rowed towards a whaling station platform in Port Hobron, Alaska, circa 1930. University of Washington Special Collections, Lagen Collection, negative UW18184.

Historic Exploitation Patterns

North Pacific

Prior to 1900, an unknown number of humpback whales were taken both in aboriginal whaling and early hand-harpoon commercial operations. Modern operations in the western North Pacific began in 1889 and in the eastern North Pacific in 1905. From 1905 through 1960, there were 23,000 humpback whales taken in modern whaling operations (Johnson and Wolman, 1984)(Fig. 20). From 1960 to 1965, over 5,000 whales were taken, reducing the North Pacific humpback whale population to around 1,000 animals by the end of 1965 (Rice, 1978a). On a more regional scale, a total of 1,871 humpback whales were taken ashore in California's Moss Landing and Trinidad whaling stations (Clapham et al., 1997). In 1965, the IWC banned the commercial hunting of humpback whales in the Pacific Ocean; however, Soviet whalers continued their take of whales until 1980 (Zemsky et al., 1995).

Eastern North Atlantic

From 1868 through 1955, at least 1,579 humpback whales were taken as part of the eastern North Atlantic and Arctic whaling operations. The number of humpback whales taken from the Faeroe Islands in the years 1868 to 1909 is unknown (Johnson and Wolman, 1984). The IWC granted this stock "Protected Status" in 1955. Nonetheless, 11 animals were still taken for local consumption between 1955 and 1967 in Norway, the Faeroe Islands, and Madiera (Brown, 1976). There are no data on the number of whales taken during Spanish and Portuguese whaling operations from the mid 1800's through the mid 1950's.

Western North Atlantic

Whaling operations for humpback whales off West Greenland began in 1886 and ended in 1976, with a total take of 522 whales (Kapel, 1979). Off Nova Scotia, Newfoundland, and Labrador, 1,397 whales were taken from 1903 to 1970 (Mitchell, 1974c). Between 1977 and 1982, there was a subsistence catch off West Greenland of 81 animals, which exceeded the IWC's recommended quota of 10 whales per year in 1978 through 1982 (IWC, 1980a).

Southern Hemisphere

There were three phases of commercial whaling for humpback whales in the Southern Oceans (Tønnessen and Johnsen, 1982; Findlay and Best, 1996). The first phase was a pre-1917 coastal operation centered around the Falkland Dependencies (1904–16) and off the coast of South Africa (1908–17), with smaller operations off Australia and New Zealand (1912–16). During this period (1904–17), an estimated 43,000 humpback whales were taken (Chittleborough, 1965), of which 25,000 were taken in the South African coastal (or bay) operations (Best, 1994b), about 3,500 were taken off the eastern coast of Africa (Best, 1994b), and about 3,157 were taken in Mozambique coastal operations (Findlay and Best, 1996).

The second phase of whaling took place in the pelagic waters of the Antarctic from 1917 to 1938, with about 28,000 humpback whales taken there during 1923–38. In 1938, the IWC began regulating catches in these south-

ern waters (Findlay and Best, 1996; Mizroch et al.[49]).

The third phase of whaling in the Southern Hemisphere was marked by post-1938 coastal whaling operations. These operations were centered in Australian and New Zealand waters, where approximately 22,000 humpback whales were taken. From 1937 to 1950, there were 5,019 humpback whales taken off southern Madagascar (Best et al., 1996; Findlay and Best, 1996). From 1953 to 1963, the pelagic whaling operations in the Antarctic were limited to only 4 days per year by IWC regulations (Findlay and Best, 1996; Mizroch et al.[49]).

[49] Mizroch, S. A., D. W. Rice, and S. Larson. 1992. Distribution of rorquals in the Southern Ocean: an atlas based on pelagic catch data. Unpubl. doc. SC/44/SHB17 submitted to Rep. Int. Whal. Comm., 40 p.

Table 10.—Total number of whales killed in the North Atlantic from 1988 to 1995 (IWC Ann. Rep., 1988–89 to 1994–95)

North Atlantic stocks	Humpback	Fin	Sei
Denmark	4		
West Greenland	1	103	
East Greenland			2
Iceland[1]		136	10
St. Vincent and the Grenadines	4		
Total strikes	9	239	12
Total kills	8	239	12

[1] Iceland did not report to the IWC after the 1989–90 season.

Current Exploitation

Table 10 summarizes the North Atlantic take of humpback whales in the seasons 1988–89 to 1994–95. During this period, there were reports of eight humpback whales taken and one struck and lost in the western North Atlantic for subsistence purposes[50] off West and East Greenland and St. Vincent and The Grenadines (IWC, 1996a).

Worldwide protection of humpback whales began in 1966, although by 1963 the IWC had already given these whales "Protected Status" in the Southern Hemisphere. Despite the official end to Southern Hemisphere whaling for humpback whales in 1963, some takes still occurred until 1980. In 1978, there was an aboriginal catch of 12 animals, including 3 calves, in the western South Pacific (Tonga). Most significant, however, was the unreported take by Soviet whaling vessels in the Antarctic from 1947 to 1980. In 1995, former Russian whaling captains revealed that 48,477 humpback whales had been taken during this time—only 2,710 of which were originally reported to the IWC (Zemsky et al., 1995; IWC, 1995a). The majority of these whales were taken in Area V (Eastern Australia), followed by Area II, Area IV, Area VI, Area III, and Area I (Fig. 9) in descending order of number of whales taken (Tormosov, 1995; IWC, 1995a).

[50] The IWC defines "subsistence" as the use of whale meat and products exclusively for local consumption as human or animal food.

Life History and Ecology

Feeding

Humpback whales in the Northern Hemisphere could be classified as generalists when it comes to their diet. They have been known to prey upon krill (euphausiids); copepods; juvenile salmonids, *Oncorhynchus* spp.; Arctic cod, *Boreogadus saida*; walleye pollock, *Theragra chalcogramma*; pollock, *Pollachius virens*; pteropods; and some cephalopods (Johnson and Wolman, 1984). In New En-

A group of humpback whales feeding in southeast Alaska. L. Gerber.

gland waters of the North Atlantic, 95% of their diets consist of fish species. The most common prey item is the Atlantic sandlance, *Ammodytes dubius*; with Atlantic herring, *Clupea harengus*; capelin, *Mallotus villosus*; Atlantic mackerel, *Scomber scombrus*; and other schooling species also found in their diets (Kenney et al., 1985). On the Alaska feeding grounds in the North Pacific, krill, herring, and capelin make up the majority of prey items in the stomachs of humpback whales (Bryant et al., 1981; Dolphin and McSweeney, 1983). In contrast, Southern Hemisphere humpback whales feed almost exclusively on Antarctic krill, *Euphausia superba* (Kawamura, 1994).

Humpback whales generally do not feed when on their wintering grounds (Slijper, 1962; Lockyer, 1981). However, there have been some documented events in low-latitude waters of whales exhibiting their characteristic feeding behaviors both in the Dominican Republic (Baraff et al., 1991) and Hawaii (Salden[51]). Feeding on wintering grounds seems to be opportunistic and is considered a rare event.

Humpback whales utilize a wide range of feeding techniques, at times involving more than one individual and resembling a form of cooperative participation. The two most observable techniques are lob-tail feeding (Weinrich et al., 1992) and bubble-cloud feeding (Fig. 21) (Ingebrigtsen, 1929; Jurasz and Jurasz, 1979a; Hain et al., 1982). Recently, there has also been documentation of bottom-feeding by humpback whales on Stellwagen Bank off Massachusetts and near the mouth of Chesapeake Bay (Swingle et al., 1993; Hain et al., 1995).

[51] Salden, D. R. 1989. An observation of apparent feeding by a sub-adult humpback whale off Maui, Hawaii (Abstr.) *In* Proceedings of the eighth biennial conference on the biology of marine mammals, 1989, Pacific Grove, Calif.

Figure 21.—An aerial view of a bubble net created by feeding humpback whales off Cape Fanshaw, Alaska. J. Olson, NMML Collection.

Reproduction

In the Northern Hemisphere, calving takes place between January and March (Johnson and Wolman, 1984) and in the Southern Hemisphere between April and September in warm, low-latitude waters. Age at sexual maturity has been estimated to range from 4 to 9 years in females, but there is no reliability associated with these estimates (Clapham and Mayo, 1987). The calving interval is also variable. A range of 2–3 years has been given (Clapham, 1990); however, there is some evidence of calving by females in consecutive years (Clapham and Mayo, 1987; Clapham, 1990; Weinrich et al., 1993; Glockner-Ferrari and Ferrari[52]). In a study looking at various reproductive parameters and survival rates, Wiley and Clapham (1993) concluded that a longer calving interval resulted in superior maternal condition. This conclusion needs further study to be considered valid for all individuals. Gestation averages around 12 months, and lactation lasts close to a year (Rice, 1967). The majority of calves are weaned at 1 year, but the specific timing of separation is still unknown (Clapham, 1992)(Fig. 22).

In the North Pacific, separate annual reproductive rates have been estimated from information collected in wintering and summering areas. In the winter areas the rate was 0.58 calves per year, and in the summer areas this rate was only 0.38 calves per year (Baker et al., 1987). In the North Atlantic, an annual reproductive rate of 0.41 calves per year has been calculated (Clapham and Mayo, 1987).

Natural Mortality

Natural mortality rates have rarely been estimated for humpback whales, and the causes of natural mortality in this species are not well known. However, Buckland (1990) used photo-identification data to estimate an annual survival rate of 0.951 (±0.010) for North Atlantic whales photographed in the Gulf of Maine.

[52] Glockner-Ferrari, D. A., and M. J. Ferrari. 1985. Individual identification, behavior, reproduction, and distribution of humpback whales, *Megaptera novaeangliae*, in Hawaii. U.S. Mar. Mammal Comm., Wash., D.C., Rep. MMC-83/06, 35 p. NTIS PB85-200772.

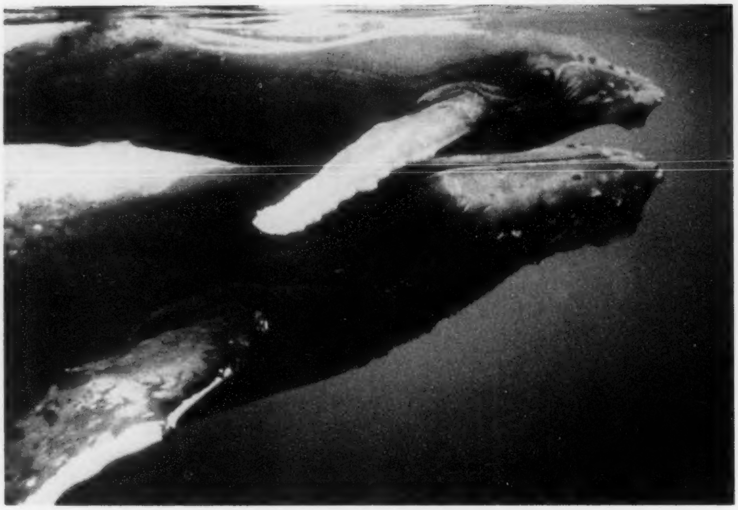


Figure 22.—Humpback whale mother and calf in clear Hawaiian waters. J. Hudnall, NMML Collection.

Killer whale, *Orcinus orca*, attacks on humpback whales do occur, although they are observed at a relatively low frequency on known wintering and summering areas (Dolphin, 1987; Whitehead, 1987). Humpback whales bear the scars of such attacks, as evidenced in 33% of photographically identified whales in the western North Atlantic (Katona et al.[53]) and 15–20% of photographically identified whales in Alaska (Dolphin, 1987). It seems most likely that younger animals during migration—when group size is lowest—may be most susceptible to this form of harassment and mortality (Dolphin, 1987; Whitehead, 1987).

Humpback whales are known to harbor many varieties of commensal and parasitic organisms (Tomilin, 1967; Matthews, 1978). Lambertsen (1992) describes infestations of the giant nematode, *Crassicauda boopis*, which causes inflammation of the renal arteries and, in severe cases, complete kidney failure. Due to particularly high levels of crassicaudosis in calves and juveniles, Lambertsen (1992) cites these infestations as a potential factor in limiting the recovery of humpback whales.

In 1987 and 1988, 14 humpback whales died from ingesting dinoflagellate saxitoxin-infected Atlantic mackerel (Blaylock et al., 1995). To what extent this type of poisoning occurs and what effects it has on the species is unknown.

From 1985 through 1998, there was an increase in the occurrence of strandings and sightings along the U.S. middle Atlantic and southeast Atlantic coasts (Swingle et al., 1993; Wiley et al., 1995). How much of this may be attributed to increased search effort and public awareness is unknown. However, some researchers have speculated that these coastal areas may be increasingly important habitat for juvenile humpback whales.

Human-related Mortality

Worldwide, humpback whales are vulnerable to a broad range of human-caused disturbances. These include vessel movements and noise on their restricted wintering grounds and fisheries activities and pollution on their feeding grounds.

Fisheries Interactions

In 1990, there were thought to be fewer than three humpback whale mortalities annually in U.S. waters due to commercial fishing operations. More recent NMFS observer data (1990–95) from the Bering Sea, Aleutian Islands, and Gulf of Alaska groundfish trawl, longline, and pot fisheries revealed no humpback mortalities in the western North Pacific stock (Hill et al., 1997). For the central North Pacific stock, the NMFS data through 1995 (i.e. observers, MMPA logbook reports, strandings) from the Hawaii and southeastern Alaska areas were used to calculate an estimated minimum mortality rate incidental to commercial fishing operations of 0.8 humpback whales per year (Hill et al., 1997). Barlow et al. (1997) report an estimated minimum mortality rate of 1.21 humpback whales per year from the California/Oregon/Washington stock, but there is no information on fisheries-related mortality when these whales are in Mexican waters during winter. Given that the PBR level[37] for whales found off California, Oregon, and Washington is estimated to be 0.5 whales per year (Barlow et al., 1995b), fisheries-related mortality off the U.S. Pacific coast may pose a threat to the recovery of this North Pacific stock. In other areas of the North Pacific (Japan, Russia, etc.) there is no information to estimate fisheries-related mortality.

In the western North Atlantic between 1975 and 1990, a minimum of 51 humpback whales were recorded as entrapped in fishing gear (i.e. bottom gillnets, lobster gear, weirs, longlines, purse seines) off the northeastern U.S. coast (Anonymous[33]). Of those entrapped whales, seven died. Total average annual estimated mortality and serious injury in fisheries under the NMFS monitoring programs (observer programs) was 0.6 whales (CV = 0.22) from 1992 to 1996 (Waring et al., 1998). Reports from other unobserved U.S. fisheries involving mortality and serious injury to humpback whales from 1991 to 1996 were found in the records of the NMFS Northeast Regional Office. These records contained 23 additional cases of mortality and serious injury related to fisheries (Waring et al., 1998). Regionally, the average number of entanglements, and thus mortalities,

[53] Katona, S. K., P. Harcourt, J. Perkins, and S. D. Kraus. 1980. Humpback whales: a catalogue of individuals identified in the western North Atlantic by means of fluke photographs. Coll. Atl., Bar Harbor, Maine, 169 p.

The NOAA research vessel, *John N. Cobb*, with a humpback whale off its port side. J. Waite, NMML Collection.

may be even greater. For example, in the 1980's, 50 (range 26–66) whales per year were entangled in Canadian waters, especially in Newfoundland (Lien et al.[54]). Given the information currently available on fishing interactions in the western North Atlantic and the current levels of PBR[37] set by the NMFS (Table 3), commercial fishing activities may pose a significant threat to the status of this stock. In other regions with known humpback whale occurrence, such as Iceland and the Denmark Strait, southwest Greenland, and southern Labrador, fisheries interaction data are scarce.

Like other baleen species, the humpback whale's distribution and health relies upon the distribution, abundance, and health of their prey. This means whale distributions shift depending on the cyclical abundance and distribution of prey items (Weinrich et al., 1997). The details of these biological/environmental changes should be a factor in their conservation status and affect the steps that are taken towards proactive management. One documented example of such an environmental change occurred in Newfoundland waters during the late 1970's when a shift in the distribution of capelin stocks caused a redistribution of humpback whales into inshore waters, where they encountered fishing gear for Atlantic cod, *Gadus morhua*, and the incidence of entanglements increased (Lien and Whitehead[55]).

Vessel Collisions

Direct ship strikes are a significant source of mortality in humpback whale stocks along the western U.S. coast (CA/OR/WA) and in the western North Atlantic. In California/Oregon/Washington feeding areas, there are an average 0.6 whales killed by ship strikes per year (Barlow et al., 1997). In the North Atlantic, 6 out of 20 humpback whales stranded along the Mid Atlantic coast between 1990 and 1994 showed signs of major ship strike injuries (Wiley et al.,1995). According to Waring et al. (1998), an annual average of 1.3 humpback whale mortalities in U.S. waters of the North Atlantic (between 1991 and 1996) could be attributed to vessel strikes. There is little information on the number of ship strikes occurring outside of U.S. waters.

Noise Disturbance

Continued coastal development and oil exploration and drilling may lead to avoidance of areas by the whales. Studies to date have shown that humpback whales exposed to playbacks of noise from drillships, semisubmersibles, drilling platforms, and production platforms do not exhibit avoidance behaviors at

[54] Lien, J., W. Ledwell, and J. Naven. 1988. Incidental entrapment in inshore fishing gear during 1988: A preliminary report to the Newfoundland and Labrador Department of Fisheries and Oceans, Canada, 15 p.

[55] Lien, J., and H. Whitehead. 1983. Changes in humpback (*Megaptera novaeangliae*) abundance off northeast Newfoundland related to the status of capelin (*Mallotus villosus*) stocks (Abstr.). *In* Proceedings of the Fifth Biennial Conference on the Biology of Marine Mammals, Nov. 1983, Boston, Mass.

levels up to 116 dB (Malme et al.[56]). However, two whales were found dead near the site of repeated subbottom blasting in a Newfoundland inlet. Studies showed no signs of avoidance or disturbance from the noise pulses, but both whales suffered severe mechanical damage to their ears (Ketten et al., 1993; Lien et al., 1993; Ketten, 1995).

Humpback whales appear most responsive to moving sound sources, such as whale-watching vessels, fishing vessels, recreational vessels, and low-flying aircraft (Anonymous, 1987; Atkins and Swartz, 1989; Beach and Weinrich, 1989; Clapham et al., 1993; Tinney[57]; Green and Green[58]). Responses to noise are variable, and the level and type of response exhibited by whales has been correlated to group size and composition and apparent behaviors at the time of possible disturbance (Watkins et al., 1981; Krieger and Wing, 1986; Glockner-Ferrari, 1990; Herman et al.[59]; Glockner-Ferrari and Ferrari[52]).

[56] Malme, C. I., P. R. Miles, P. Tyack, C. W. Clark, and J. E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. Rep. from BBN Labs Inc., Cambridge, Mass., for U.S. Minerals Manage. Serv., Anchorage, Alaska. BBN Rep. 5851; OCS Study MMS 85-0019.

[57] Tinney, R. T., Jr. 1988. Review of information bearing upon the conservation and protection of humpback whales in Hawaii. Rep. for U.S. Mar. Mammal Comm., Wash., D.C., 56 p. NTIS PB88-195359.

[58] Green, M. L., and R. G. Green. 1990. Short-term impact of vessel traffic on the Hawaiian humpback whale (*Megaptera novaeangliae*), 9 p. Pres. at Annu. Meet. Anim. Behav. Soc., June 1990, Buffalo, N.Y.

[59] Herman, L. M., P. H. Forestell, and R. C. Antinoja. 1980. The 1976/1977 migration of humpback whales into Hawaiian waters: composite description. Rep. MMC-77/19 for the U.S. Mar. Mammal Comm., Wash., D.C., 55 p. NTIS PB80-162332.

There is the possibility that long-term displacement may have resulted from vessel noise disturbance in the central North Pacific stock, where researchers have noted a decline in the use of Glacier Bay, Alaska, during feeding seasons (Jurasz and Jurasz[60]; Dean et al.[61]) and avoidance of near-shore waters by mothers and calves in Hawaii (Salden, 1988; Glockner-Ferrari, 1990; Glockner-Ferrari and Ferrari[52]). Humpback whales may also become habituated to vessel traffic and its associated noise (Watkins, 1986; Belt et al.[62]), which may leave them more vulnerable to vessel strikes (Swingle et al., 1993; Wiley et al., 1995). In Hawaii, regulations prohibit boats from approaching within 91 m of adult whales and within 274 m in areas designated mother/calf areas (Anonymous, 1987). Likewise, in Alaska, the number of cruise ships entering Glacier Bay has been limited to reduce possible disturbance (Baker et al., 1988).

Classification Status

The humpback whale was listed as endangered under the ESA in 1973 and designated as depleted under the MMPA. Endangered status is applied to all stocks in U.S. waters (Anonymous, 1994b). In addition, all stocks are classified as "Protected Stocks" by the IWC. Under this designation, the IWC recognizes that these whales are 10% or more below their maximum sustainable yield (MSY) levels (IWC, 1995b).

[60] Jurasz, C. M., and V. P. Jurasz. 1979. Ecology of humpback whales. Contr. cx-9000-7-0045. Draft rep. for U.S. Natl. Park Serv., Anchorage, Alaska, 118 p.

[61] Dean, F. C., C. M. Jurasz, V. P. Palmer, C. H. Curby, and D. L. Thomas. 1985. Analysis of humpback whale (*Megaptera novaeangliae*) blow interval data/Glacier Bay, Alaska, 1976-1979, 224 p., 2 vol. Rep. from Univ. of Alaska, Fairbanks, for U.S. Natl. Park Serv., Anchorage, Alaska.

[62] Belt, C. R., M. T. Weinrich, and M. R. Schilling. 1989. Behavioral development of humpback whales in the southern Gulf of Maine (Abstr.). *In* Proceedings of the eighth biennial conference on the biology of marine mammals, 1989, Pacific Grove, Calif.

All humpback whale stocks in U.S. waters are adversely affected by human activities (Table 3, 11) (Barlow et al., 1997; Hill et al., 1997; Waring et al., 1998). There is no information on the extent of the effects of human activity on humpback whale stocks in the eastern North Atlantic, western North Pacific, Mexico, and Southern Hemisphere.

With a few notable exceptions (see below), there has been little advance in the accuracy and availability of population parameters, abundance, or stock identity worldwide since Braham's 1991 status review[3]. Forthcoming results of the YoNAH project should help resolve some uncertainties about genetic stock structure and the distribution of humpback whales in the North Atlantic (Allen et al.[44]). Genetic analysis holds promise in distinguishing between biological stocks, but at this time the number of whales sampled is too small to be of statistical value (Baker et al., 1994; IWC, 1995a). A second phase of the YoNAH project is being discussed. These further studies would provide population trend data.

During a recent (1997) workshop on the reevaluation of North Pacific humpback whale classification, Gerber and DeMaster[63] reported that the partici-

[63] Gerber, L. R., and D. P. DeMaster. 1997a. Report on workshop to develop Endangered Species Act classification criteria for North Pacific humpback whales. Natl. Mar. Mammal Lab., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. Unpubl. rep., 16 p.

Table 11.—Factors possibly influencing the recovery of humpback whales under the ESA (1973)§4(a)(1),1992 Amend. (eastern North Atlantic and Southern Hemisphere data are not available).

Factor	North Pacific	Western North Atlantic
1. Present or threatened destruction or modification of habitat	Central stock: Vessel traffic; oil and gas exploration	Vessel traffic; channel dredging; oil and gas exploration; coastal development
2. Overutilization for commercial, subsistence, recreational, scientific, or educational purposes	Central stock: Whale watching, scientific research, photography, and associated vessel traffic	Whale watching, scientific research, photography, and associated vessel traffic; West Greenland, St. Vincent and the Grenadines harvests
3. Disease or predation	Unknown	Saxitoxin
4. Other natural or man-made factors	Central stock: Entanglement in fishing gear	Vessel collisions; entanglement in fishing gear (e.g. bottom gillnets, lobster gear, weirs, longlines, purse seines); human depletion of fish stocks

pants had concluded that the criteria used to classify humpback whales should incorporate uncertainties from the available data (e.g. abundance, trends in abundance) and be flexible enough to accommodate multiple population structure scenarios. Gerber and DeMaster[64] developed classification criteria based on abundance, trends in abundance, changes in distribution, and regulatory status. Trends in population abundance over time were used to generate a probability distribution around the population's underlying rate of change, which could be used to designate potential thresholds for endangered and threatened status. According to thresholds generated by their model, a recommendation to downlist to threatened the central North Pacific humpback whale stock would be warranted. However, they also noted that more accurate information on life history parameters, trends in abundance, sex ratio, environmental variability, and stock structure must continue to be collected and applied to such classification models in order to make accurate status determinations. Reliable abundance estimates exist for the central North Pacific humpback whale stock, and there are indications of its continued growth.

Assuming that abundance levels are accurate and continue to increase, anthropogenic threats are reduced, adequate monitoring plans are developed and implemented, and information on population trends continue to be collected, the western North Atlantic and central North Pacific stocks should be considered for downlisting to threatened status.

[64] Gerber, L. R., and D. P. DeMaster. 1997b. An approach to Endangered Species Act classification of North Pacific humpback whales. Avail. from Leah Gerber, Natl. Mar. Mammal Lab., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

The Blue Whale, Pygmy Blue Whale, and the Antarctic or True Blue Whale

Introduction

The Northern Hemisphere blue whale, *Balaenoptera musculus musculus* Linnaeus 1758; the pygmy blue whale, *Balaenoptera musculus brevicauda* Ichihara 1966; and the true blue whale[65], *Balaenoptera musculus intermedia* Burmeister 1871, are members of the Balaenopteridae family whose subspecies contain the largest animals ever known to have lived on Earth (Rice[12]). Adult blue whales can attain lengths of about 30 m and weigh up to 160 t in the Southern Oceans (Mackintosh, 1942). In the North Atlantic and North Pacific, their maximum lengths have been recorded at 27 m (True, 1904) and 26.8 m (Reeves et al., 1985), respectively. They are gray in color (appearing blue below the water surface) with distinct gray and white mottling, while their ventral surface is lighter in color. Their dorsal fin is relatively small (Fig. 23). Like other balaenopterids, they have fringed baleen plates instead of teeth and ventral grooves which allow for the filtering of large quantities of water during feeding on swarms of euphausiids.

Rice[12] recognizes the *B. musculus* subspecies based on body size and geographic distribution. *B. m. intermedia*, which occurs in the high latitudes of the Southern Oceans, is the largest (maximum length = 30 m), *B. m. musculus* of the Northern Hemisphere is slightly smaller (maximum length = 27 m), and *B. m. brevicauda* (pygmy blue whale) in the mid latitude waters of the southern Indian Ocean and north of the Antarctic Convergence is the smallest (Ichihara, 1966; Omura et al., 1970; Kato et al., 1995; Gilpatrick et al.[66]). Distinguishing between the subspecies is difficult at sea and, therefore, information on population size and distribution for each subspecies may be unreliable.

Distribution and Migration

Blue whale distribution is worldwide (Fig. 24). Presumably they follow a migration pattern of seasonal north-south movements between summering and wintering areas, but some evidence suggests that individuals in certain areas remain in low latitudes year-round (Donovan, 1984; Yochem and Leatherwood, 1985; Reilly and Thayer, 1990). The location of wintering areas is still somewhat speculative (Jonsgård, 1966; Mackintosh, 1966), whereas known summer feeding areas are in the relatively high latitudes. Migratory routes are not well known, mainly because blue whales occur primarily in the open ocean.

North Pacific

Blue whales are found along the coastal shelves of North America and South America in the Pacific Ocean (Rice, 1974; Clarke, 1980; Donovan, 1984). The IWC Scientific Committee recognized one blue whale stock in the North Pacific (Donovan, 1991). However, there is increasing evidence suggesting that more than one stock exists within this ocean basin (Ohsumi and Wada, 1974; Mizroch et al., 1984a; Barlow et al., 1994b; Braham[3]; Gilpatrick et al.[66]). One such tentative stock designation is for blue whales occuring during winter off Baja California and in the Gulf of California (Fig. 4). Photo-identification studies have shown that individuals from these concentrations travel in summer and fall to waters off California (Calambokidis et al., 1990; Barlow et al., 1997; Sears et al.[67]). Preliminary studies of these California/Mexico whales, based on body-length data from whaling records and aerial photogrammetry, indicate that they are morphologically distinct from blue whales of the western and central North Pacific (Gilpatrick et al.[66]).

Acoustic monitoring has resulted in blue whale vocalizations being recorded off Oahu, Hawaii, and the Midway Islands (Northrop et al., 1971; Thompson and Friedl, 1982), although sightings or strandings in Hawaiian waters have not been reported. Nishiwaki (1966) noted the occurrence of blue whales near the Aleutian Islands and in the Gulf of Alaska. However, as of 1987, there have been no blue whale sightings in these waters (Leatherwood et al., 1982; Stewart et al., 1987; Forney and Brownell[68]). No distributional information exists for the western North Pacific Ocean.

[65] *B. m. intermedia* is referred to in the literature by three common names: Antarctic blue whale, southern ordinary blue whale, and the true blue whale. To avoid confusion, this review refers to this subspecies as the "true" blue whale.

[66] Gilpatrick, J. W., W. L. Perryman, and R. L. Brownell. 1997. Geographic variation in North Pacific and Southern Hemisphere blue whales (*Balaenoptera musculus*). Unpubl. doc. SC/49/09, 33 p., submitted to Rep. Int. Whal. Comm.

[67] Sears, R., M. Berube, and D. Gendron. 1987. A preliminary look at the distribution and migration of blue whales (*Balaenoptera musculus*) in the northeast Pacific, based on the photo-identification of individuals (Abstr.). *In* Proceedings of the Seventh Biennial Conference on the Biology of Marine Mammals, 1987, Miami, Fla.

[68] Forney, K. A., and R. L. Brownell. 1996. Preliminary report of the 1994 Aleutian Island marine mammal survey. Unpubl. doc. SC/48/011, 15 p., submitted to Rep. Int. Whal. Comm.

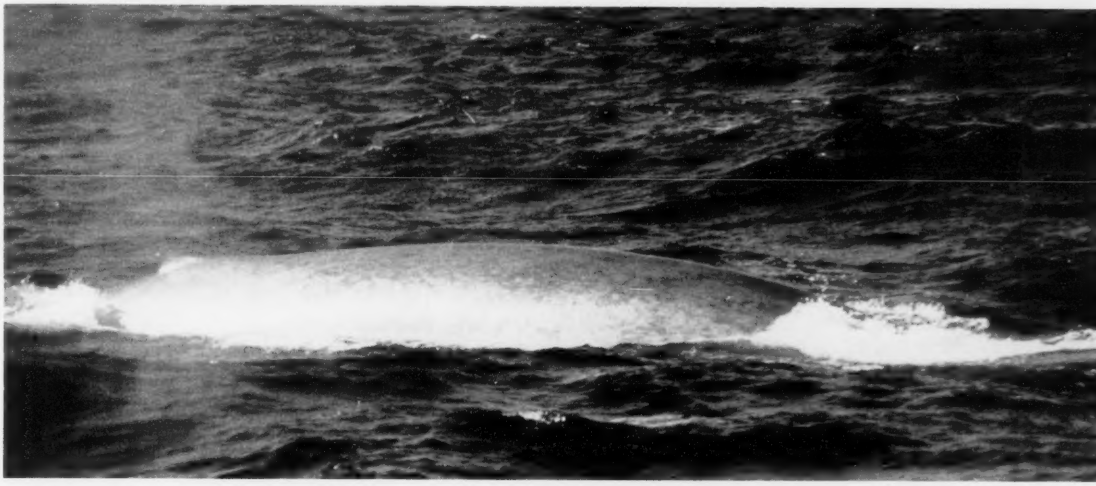


Figure 23.—A blue whale surfacing. Note the mottled coloration and very small dorsal fin. J. M. Waite, NMML Collection.

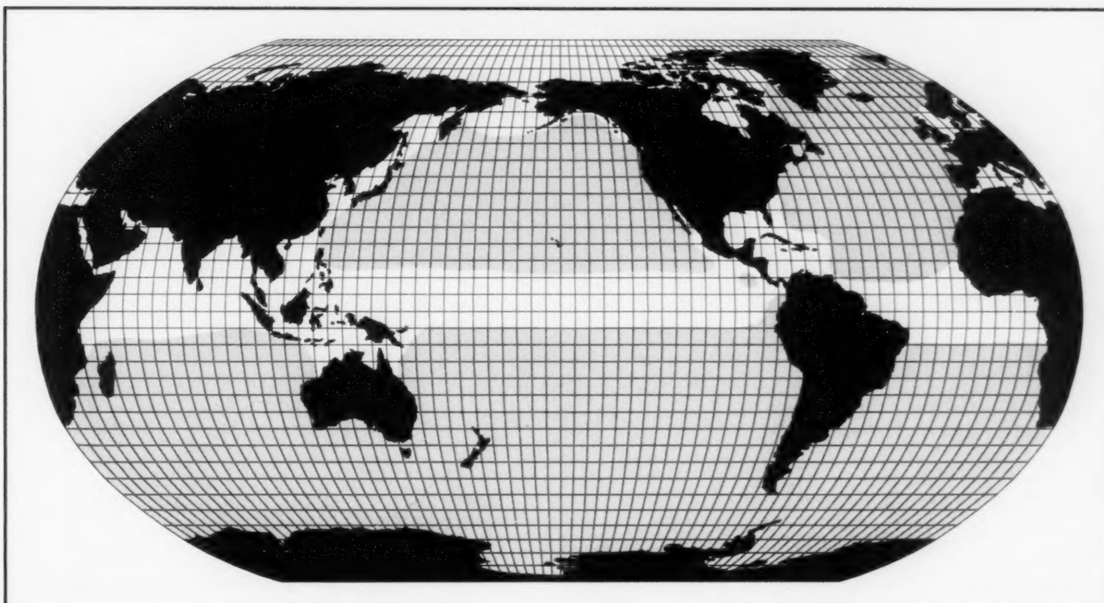


Figure 24.—Worldwide distribution of all blue whale species. Adapted from Mizroch et al. (1984a).

The Costa Rica Dome (centered roughly around lat. 9°N, long. 89°W) is a stationary eddy in the eastern tropical Pacific Ocean which appears to be an important year-round habitat for blue whales (Fig. 13) (Reilly and Thayer, 1990). Reilly and Thayer (1990) suggested four reasons for this year-round presence: 1) the standing stock of prey (i.e. euphausiids) that results from this highly productive area, 2) the aggregation of juvenile, nonmigratory whales, 3) the occurrence of a resident stock of Northern Hemisphere blue whales, or 4) temporal overlap, when both Northern and Southern Hemisphere whales utilize the area. Blue whales have been sighted in the Dome area in all seasons, but there is a peak in occurrence from June through November.

North Atlantic

Blue whales are found from the Arctic to at least the mid latitude waters of

the North Atlantic with occasional occurrences in U.S. Exclusive Economic Zone (EEZ)[69] waters (Yochem and Leatherwood, 1985; Wenzel et al., 1988; CeTAP[70]; Gagnon and Clark[71]). These whales are currently recognized as one stock by the IWC (Donovan, 1991).

Sightings of blue whales occur most frequently off eastern Canada. During winter, they are found in the waters off Newfoundland. In summer, they are found in Davis Strait (Mansfield, 1985), in the Gulf of St. Lawrence (from the north shore of the St. Lawrence River estuary to the Strait of Belle Isle), and off eastern Nova Scotia (Fig. 6) (Sears et al.[67]).

In 1992, the U.S. Navy and its contractors conducted an extensive acoustic survey of the North Atlantic using the Integrated Underwater Surveillance System's (IUSS) fixed acoustic array (Clark, 1995). This study provided information on the seasonality and geographic distribution of several baleen whale species' vocalizations (Clark et al.[72]). Localizations of the sounds indicated concentrations of blue whales on the Grand Banks off Newfoundland and west of the British Isles. One blue whale was tracked acoustically for 43 days, during which time it traveled 1,400 n.mi in an area that included waters northeast of Bermuda to the southwest and west of Bermuda (Gagnon and Clark[71]).

Northern Indian Ocean

Blue whales have been reported year-round in the northern Indian Ocean. Sightings have been reported from the Gulf of Aden, Persian Gulf, Arabian Sea, and across the Bay of Bengal to Burma and the Strait of Malacca (Fig. 12, 14) (Mizroch et al., 1984a). The migratory movements of these whales are unknown.

Southern Hemisphere

Blue whales in the Southern Hemisphere are assigned to six stock areas designated by the IWC (Fig. 9) (Donovan, 1991). These areas are consistent with the presumed blue whale feeding locations, although reliable distributional information on blue whales is still scarce. Historical catch records indicate that the true blue whale and the pygmy blue whale may be geographically segregated (Kato et al., 1995; Brownell and Donahue[73]). The distribution of the pygmy blue whale is north of the Antarctic Convergence, while that of the true blue whale is south of the Convergence in the austral summer (Fig. 10) (Kato et al., 1995). True blue whales occur mainly in the relatively high latitudes. During summer, the true blue whale is found close to the ice edge (south of lat. 58°S) with concentrations between lat. 66–70°S and long. 60–80°E (Fig. 10) (Kasamatsu et al., 1996). No new information on wintering areas has been reported since Braham's 1991 status review[3]; therefore, there are no data to validate IWC stock designations in the Southern Hemisphere.

Current and Historical Abundance

North Pacific

Gambell (1976) provided a population estimate for the entire North Pacific of 1,600 blue whales (range = 1,400–1,900; no CV or CI provided) based on history of catches and trends in CPUE[22]. However, this estimate is likely no longer realistic. From ship-based line transect surveys off California in 1991–93 and off California, Oregon, and Washington in 1996, Barlow[74] estimated 1,927 (CV=0.16) blue whales for these areas. Off the coast of Oregon and Washington, no blue whales were sighted during an aerial survey in 1991 (Green et al.[75]) or during ship-based line transect surveys in 1996 (Barlow[74]). In the eastern tropical Pacific, Wade and Gerrodette (1993) estimated 1,415 (CV = 0.243) blue whales from ship-based line transect survey data. There are no statistically reliable population estimates for the eastern North Pacific north of the State of Washington or in the western North Pacific. Nonetheless, it appears that at a minimum there are currently over 3,300 blue whales in the North Pacific (Wade and Gerrodette, 1993; Barlow[74]).

According to calculations based on historic whaling data, there were an estimated 4,900 (no CV available) blue whales inhabiting the North Pacific prior to commercial exploitation (Gambell, 1976). Admittedly, estimates such as these are rather speculative.

North Atlantic

Braham[3] provided a population estimate for the entire North Atlantic of between 100 and 555 blue whales based on history of catches and trends in CPUE[22]. This estimate is not considered statistically reliable by the IWC. Ongoing photo-identification studies (since 1979) in the Gulf of St. Lawrence have cataloged over 320 individual blue whales (Sears et al., 1990). There is evidence from ship-based surveys west and southwest of Iceland that blue whale abundance has been steadily increasing since the late 1950's; and from 1979 to 1998 at a rate of 5.2% (CV = 0.22) per year (Sigurjónsson and Gunnlaugson, 1990). There is no statistically reliable estimate of blue whale abundance in the eastern North Atlantic.

[69] The EEZ of a maritime country includes all waters of the continental shelf, continental slope, and extends roughly 200 n.mi from the coast seaward.

[70] CeTAP. 1982. A characterization of marine mammals and turtles in the mid and North Atlantic areas of the U.S. outer continental shelf. Cetacean and Turtle Assessment Program, Univ. R.I. Final rep. #AA551-CT8-48 to Bur. Land Manage., Wash., D.C., 538 p.

[71] Gagnon, C. J., and C. W. Clark. 1993. The use of U.S. Navy IUSS passive sonar to monitor the movement of blue whales (Abstr.). *In* Proceedings of the Tenth Biennial Conference on the Biology of Marine Mammals, 1993, Galveston, Tex.

[72] Clark, C. W., C. J. Gagnon, and D. K. Mellinger. 1993. Whales '93: the application of the Navy IUSS for low-frequency marine mammal research (Abstr.). *In* Proceedings of the Tenth Biennial Conference on the Biology of Marine Mammals, 1993, Galveston, Tex.

[73] Brownell, R. L., and M. A. Donahue. 1994. Southern Hemisphere pelagic whaling for pygmy blue whales: review of catch statistics. Unpubl. doc. SC/46/SH6 submitted to Rep. Int. Whal. Comm., 9 p.

[74] Barlow, J. 1997. Table 2. Minutes from the fifth meeting of the U.S. Pacific Scientific Review Group Meeting, October 1997, La Jolla, CA. Available from D. P. DeMaster, Natl. Mar. Mammal Lab., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

[75] Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnell, and K. C. Balcomb. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989–1990. Final rep. to Minerals Manage. Serv., Contr. 14-12-0001-30426, completed May 1992.

Figure 25.—Partly flensed blue whale awaiting further processing at an Alaska whaling station. University of Washington Special Collections, Lagen Collection, negative UW18185.

Based on whaling records, Gambell (1976) estimated that from 1,100 to 1,500 blue whales occured in the entire North Atlantic prior to commercial exploitation (Gambell, 1976), although according to the IWC's Scientific Committee this estimate is statistically unreliable.

Northern Indian Ocean

There are no estimates of current or historic abundance for this blue whale stock.

Southern Hemisphere

Since 1965, there have been only seven sightings of true blue whale calves in waters south of lat. 60°S (Braham[3]) despite IWC/IDCR surveys in these areas. The Scientific Committee agreed that, while a reliable estimate of abundance of Southern Hemisphere blue whales could not be developed because data on these stocks were incomplete, there were more than 500 blue whales in the Southern Oceans (IWC, 1990). More recently, the IWC calculated an abundance estimate of 1,255 blue whales (no CV available) by combining data from IWC/IDCR and Japanese Sighting Vessel (JSV) surveys from 1978 to 1988 (IWC, 1996a).

Prior to the start of Antarctic commercial exploitation in the early 1900's, there were an estimated 180,000 (range = 150,000–210,000) true blue whales in the Southern Hemisphere (Gambell, 1976). Based on a comparison of current and historic estimates, some researchers noted that southern blue whale stocks do not appear to be recovering from exploitation (Table 4) (Hatanaka and Komatsu[76]).

In the mid 1970's, the southern Indian Ocean's pygmy blue whale population was estimated at 5,000 individuals (no CV available) (Gambell, 1976). An estimated 10,000 (no CV available) pygmy blue whales inhabited this ocean historically (Gambell, 1976).

Historic Exploitation Patterns

In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the exploitation of blue, fin, and sei whales, which are generally larger and faster than previously exploited humpback and right whales. Whalers in the North Pacific and Antarctic soon added this modern equipment to their arsenal. As this new technology spread and began to receive widespread use, blue whale populations began declining worldwide. Subsequently, the whaling industry shifted its effort away from declining blue whale stocks to other large whale species and then resumed hunting blue whales when they appeared more abundant. The result was a cyclical rise and fall, leading to severe depletion of blue whale stocks worldwide (Mizroch et al.[49]).

North Pacific

From 1889 until 1965, approximately 5,761 blue whales were taken from the North Pacific (Braham[3]). Evidence of a population decline can be seen in Japanese catch data. In 1912, 236 blue whales were caught, and from 1913 to 1965, the catch numbers declined continuously (Fig. 25) (Mizroch et al., 1984a). Since the IWC banned commercial whaling in the North Pacific in 1966, no blue whales have been reported taken from those waters.

North Atlantic

By 1882, Norway's whaling operations, which had originally focused on blue whales, began to take more fin whales due to the scarcity of the former (Mizroch et al., 1984a). The search for blue whales expanded to include waters off Iceland, the Faeroe Islands, Newfoundland, Svalbard (Spitsbergen), and the islands off the British coast (Fig. 6, 7, 18).

From the early 1880's through 1915, there were 6,000 blue whales taken

[76] Hatanaka, H., and M. Komatsu. 1993. International action plan for recovery of large whales—towards recovery of blue whales. Unpubl. doc. SC/45/SHBa27 submitted to Rep. Int. Whal. Comm., 3 p.

from land-based stations in Iceland (Sigurjónsson and Gunnlaugsson, 1990). In 1915, the Icelandic Parliament prohibited all land-based whaling due to the apparent depletion of blue and humpback whales. By 1935, whaling had resumed from one land-based station in western Iceland and continued for 5 years, a period in which 30 blue whales were taken. By 1952, fewer than 15 blue whales were taken per year by all Icelandic whalers (Mizroch et al., 1984a). The IWC provided complete protection to the blue whale in the North Atlantic in 1955, but whaling continued off the coasts of Iceland until 1960. From the close of World War II to 1960, 163 blue whales were taken off Iceland (Sigurjónsson and Gunnlaugsson,1990). Since 1985, there have been no reported takes of blue whales in the North Atlantic.

Southern Hemisphere

A total of 330,684 blue whales (all subspecies) were taken in the Southern Hemisphere between 1909 and 1967 (Braham[3]). Commercial harvest of blue whales amounted to a take of approximately 2,000–6,000 whales per year from 1914 to 1924 in this region. But when factory whaling ships were introduced in the late 1920's, the take increased to 12,734 in the 1928–29 season and to 29,410 in the 1930–31 season (Mizroch et al., 1984a). These ships allowed more efficient processing of whales at sea and led to the rapid decline of blue whale stocks in the Southern Hemisphere. By 1938 the number of fin whales being caught was more than twice the number of blue whales caught (14,923) in the Southern Hemisphere during the previous three decades (Mizroch et al., 1984a). Commercial hunting of blue whales in the Southern Oceans was banned by the IWC in 1967.

The recent release of withheld Soviet whaling records shows a discrepancy in the number of true blue whales originally reported caught by the U.S.S.R. in southern waters between 1947 and 1980 (Zemsky et al., 1995). Originally, a take of 3,651 true blue whales was reported to the IWC for this period, but the recently revealed data show that only 3,462 true blue whales were taken (IWC, 1995a). This is most likely due to the misidentification of pygmy blue whales in the original data and is a possible problem in the interpretation of catch data from other countries as well.

Current Exploitation

The current catch limit imposed by the IWC is zero for all blue whale stocks (IWC, 1995b).

Life History and Ecology

Feeding

Blue whale distribution is likely linked to nutritional requirements (Reilly and Thayer, 1990; Schoenherr, 1991; Kawamura, 1994). Areas of cold, upwelling currents (i.e. eastern sides of the oceans) provide large quantities of euphausiid crustaceans (krill) which is a primary prey item of blue whales. Areas of dense prey aggregations may be seasonal, year-round, or strongly influenced by the occurrence of El Niño Southern Oscillation (ENSO) events (Reilly and Thayer, 1990; Schoenherr, 1991; Gendron and Sears, 1993). The krill species on which these whales rely include: *Euphausia pacifica, Thysanoessa inermis, T. longipes,* and *T. spinifera* (Schoenherr, 1991) in the North Pacific; *Meganyctiphanes norvegica* and *T. inermis* in the North Atlantic; and *E. superba* (Kawamura, 1994), *E. crystallorophias,* and *E. vallentini* in the Antarctic (Nemoto, 1959). Off the Pacific coast of Baja California, blue whales have been reported to feed on concentrations of the pelagic red crab, *Pleuroncodes planipes* (Rice, 1978b). However, blue whales have been observed between February and April within the Gulf of California feeding on surface swarms of *Nyctiphanes simplex*, a euphausiid species (Sears, 1990; Gendron and Sears, 1993). Sears (1990) regarded the latter species as the principal prey of blue whales in the region.

Some researchers have speculated that a critical factor influencing blue whale recovery in the Southern Hemisphere may be interspecific competition with minke and nonwhale krill predators (Fraser et al., 1992). However, no conclusions can be made about this type of competition until further behavioral and distributional information is collected, especially with a focus on ecosystem requirements of baleen whales (Kawamura, 1994; Clapham and Brownell, 1996).

Reproduction

Both male and female blue whales reach sexual maturity at 5–15 years of age. Females give birth to a single 7–8 m calf every 2 or 3 years after a gestation period of approximately 12 months (Mizroch et al., 1984a). Calves are weaned late the following summer at around 7 months and at a length of about 16 m (Mizroch et al., 1984a; Anonymous, 1994a). However, it must be noted that these reproductive parameters are not current, because the IWC has gathered little new information since 1967 (Mizroch et al., 1984a).

Natural Mortality

Nothing is known of natural mortality in blue whales. They appear to be relatively free of ecto- and endoparasites (Rice, 1978b). Lampreys are found attached to the dermal surface of large whales in warmer waters. The killer whale, *Orcinus orca*, may prey on blue whales, but, this may be rare. It is possible that immature or weakened animals may become targets for killer whales under certain conditions (Tarpy, 1979). Natural mortality rates are unknown, but they are likely to be similar to those of the fin whale—about 4% per year in adult whales (Allen, 1980).

Human-related Mortality

Fisheries Interactions

There are no reports of fisheries-related mortality or serious injury in any of the blue whale stocks. However, Barlow et al. (1997) noted that a conflict may exist in the offshore drift gillnet fishery in the North Pacific (i.e. off California). Blue whale interactions with fisheries may go undetected because the whales are not observed after they swim away while carrying fishing gear. Fishermen report that large blue and fin whales usually swim through the nets without entangling and with very little damage to the net (Barlow et al., 1997). In U.S. North Atlantic waters, the total mortality and serious injury from fisheries-related incidents is considered insig-

Table 12.—Factors possibly influencing the recovery of blue whales under the ESA (1973)§4 (a)(1),1992 Amend. (northern Indian Ocean and Southern Hemisphere data are not available).

Factors	North Pacific	North Atlantic
1. Present or threatened destruction or modification of habitat	Offshore oil and gas development	Offshore oil and gas development; noise from vessel traffic
2. Overutilization for commercial, recreational, scientific, or educational purposes	Whale watching, scientific research, photography, and associated vessel traffic	Whale watching, scientific research, photography, and associated vessel traffic
3. Disease or predation	Unknown	Unknown
4. Other natural or man-made factors	Vessel collisions; entanglement in fishing gear (e.g. offshore drift gillnet)	Vessel collisions

nificant, but blue whale/fishery interactions have not been thoroughly investigated for impacts (Waring et al., 1998).

Vessel Collisions

It is possible that mortality from ship strikes affects all blue whale stocks. Additional mortality due to vessel strikes likely goes unreported because the bodies of injured or killed animals did not strand or investigations of stranded animals did not reveal the trauma of a ship collision.

In 1980, 1986, 1987, and 1993, ship strikes have been implicated in the deaths of blue whales off California (Barlow et al., 1997). In addition, several photographically identified blue whales from California waters were observed with large scars on their dorsal areas that may have been caused by ship strikes. In the California/Mexico stock, annual incidental mortality due to ship strikes averaged 0.2 whales during 1991–95 (Barlow et al., 1997). However, the effect that this type of mortality or injury may have on the status of blue whale stocks is currently unknown.

More recently, in March 1998 a juvenile male blue whale was reportedly struck and killed by a commercial vessel and was carried on the bow of the vessel into Narragansett, R.I. The necropsy of this whale indicated that death occurred as a result of a ship strike, including bone fractures at several locations along one side of the animal's body (Anonymous, 1998). The PBR level[37] for the western North Atlantic blue whale is currently 0.6 whales per year (Waring et al., 1998). Clearly, if vessel collisions occur frequently, blue whale recovery in U.S. Atlantic waters will be affected. However, the frequency of such mortalities is poorly documented.

Noise Disturbance

Studies have shown that blue whales respond to the sound created by approaching vessels in a variety of ways, depending on the behavior of the animals at the time of approach and on speed and direction of the approaching vessel. Blue whales involved in feeding react less rapidly and with less obvious avoidance maneuvers than those not involved in feeding (Richardson et al., 1995). Within the St. Lawrence River estuary, heavy recreational and commercial vessel traffic from several sources (e.g. industrial freight, whale watching) may affect summering blue whales. Studies in the St. Lawrence River showed the most evident reactions to these vessels occurred when boats made fast, erratic approaches or sudden changes in direction or speed (Edds and MacFarlane, 1987; MacFarlane[77]).

Noise disturbance from seismic exploration apparently does not affect blue whales in any significant manner. When noise pulses from air guns were produced off Oregon, blue whales in the area continued vocalizing at the same rate as before the pulses, suggesting they were undisturbed by the noise (McDonald et al., 1993).

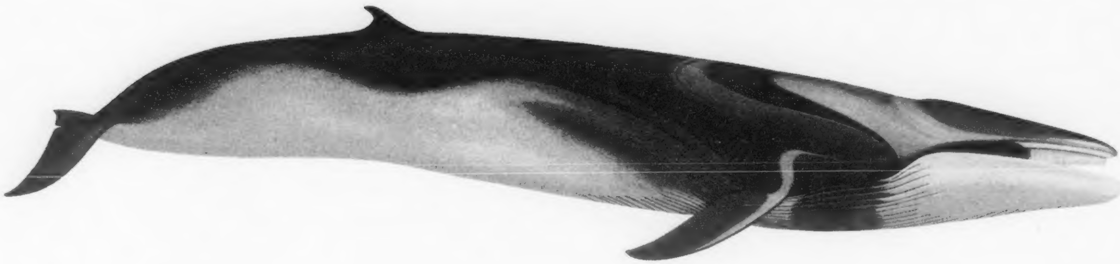
Classification Status

The blue whale was listed as endangered under the ESA in 1973 and given protection under the MMPA. All blue whale stocks in U.S. waters are listed as endangered (Anonymous, 1994a). Internationally, all blue whale stocks are classified as "Protected Stocks" by the IWC. Under this designation, the IWC recognizes that these stocks are 10% or more below their maximum sustainable yield (MSY) levels (IWC, 1995b).

[77] MacFarlane, J. A. F. 1981. Reactions of whales to boat traffic in the area of the confluence of the Saguenay and St. Lawrence Rivers, Quebec. Unpubl. doc., 50 p.

The accuracy and availability of abundance estimates and stock identity has not improved since Braham's 1991 status review[3], with the exception of the blue whales that occur off California and Mexico. The IWC has suggested long-term acoustic surveys and satellite tracking in addition to visual survey methodology to better evaluate the density and distribution of blue whales in the Southern Hemisphere (IWC, 1996a). These suggestions are also applicable to stocks in the Northern Hemisphere. In addition, genetic analysis holds promise for distinguishing between true and pygmy blue whales in the Southern Hemisphere (IWC, 1996a).

The factors possibly influencing the status of blue whales are summarized in Table 12. A Recovery Plan for blue whales has been prepared by the NMFS in which measures to protect and monitor the recovery of this species are identified (Anonymous, 1998). At this time, however, any reevaluation of blue whale status awaits the collection of more reliable information on stock structure, distribution and migration patterns, trends in abundance, causes of mortality, and factors influencing the recovery of blue whale stocks, as well as the development of objective delisting criteria. Therefore, until such information is available, the classification status of all blue whale stocks should remain unchanged. However, abundance in the California/Mexico region of the eastern North Pacific may be increasing to approximately 30% of its preexploitation levels. If new abundance trend data indicate that such increases continue, blue whales in this region may be candidates for a consideration to downlist from endangered to threatened.



The Fin Whale

Introduction

The fin whale, *Balaenoptera physalus* Linnaeus 1758, is the second largest member of the family Balaenopteridae (after the blue whale, *B. musculus*). Mature animals range from 20 to 27 m in length, with mature females being approximately 1.47 m longer than mature males (Aguilar and Lockyer, 1987). All fin whales have a consistent pattern of asymmetrical pigmentation which is particularly recognizable on the head region. The whale's underside, right lip, and right baleen plate are yellow-white, while their main body, left lip, and left baleen plate are a fairly uniform gray-blue color. This asymmetry may be linked to the whale's feeding behavior, but there is no evidence that their unusual coloration gives them any type of predatory advantage over other balaenopterids (Tershy and Wiley, 1992). The dorsal fin is generally falcate with a pointed tip, but it may be quite variable in its shape (Fig. 26).

The fin whale is usually found alone or in small groups, and the species appears to have no well-defined social structure. Like other balaenopterids, they have fringed baleen plates instead of teeth, and ventral grooves which expand during feeding and allow the whale to engulf large quantities of water along with small crustacean and fish prey items.

Distribution and Migration

Fin whales inhabit a wide range of latitudes between lat. 20–75°N and 20–75°S (Fig. 27) (Mackintosh, 1966; Leatherwood et al., 1982; Anonymous, 1994a). Most migrate seasonally from relatively high-latitude Arctic and Antarctic feeding areas in the summer to relatively low-latitude breeding and calving areas in winter. Arrival time on the summer feeding areas may differ according to sexual class, with pregnant females arriving earlier in the season than other whales (Mackintosh, 1965). The location of winter breeding areas is still uncertain. These whales tend to migrate in the open ocean, and therefore migration routes and the location of wintering areas are difficult to determine.

North Pacific

The IWC's Scientific Committee recognized two management stocks in the North Pacific: the East China Sea (Fig. 5) and the rest of the North Pacific (Donovan, 1991). One reason for this broad desig-

Figure 26.—Two fin whales, one noticeably smaller, surface simultaneously revealing their falcate dorsal fins and dark coloration. S. Hill, NMML Collection.

nation is the lack of data on geographic or genetic separation within the species. Because fin whales tend to inhabit such a wide range of latitudes in all seasons, it is hard to predict where individual animals travel during pelagic migrations.

Mizroch et al. (1984b) suggested five possible stocks within the North Pacific based on histological and tagging experiments (Fig. 4, 5) (Fujino, 1960; Rice, 1974; Tershy et al., 1993):

1) East and West Pacific (intermingling around the Aleutian Islands),
2) East China Sea,
3) British Columbia,
4) Southern/Central California to Gulf of Alaska, and
5) Gulf of California.

Discovery tags[38] injected and sometimes recovered during the era of commercial whaling demonstrated possible southern California wintering areas and summering areas ranging from central California to the Gulf of Alaska (Rice, 1974). Other researchers have more recently found year-round concentrations of fin whales off the southern and central California coast, although there is a seasonal peak during the summer and autumn (Barlow, 1995; Forney et al., 1995; Dohl et al.[78]). Fin whales have also been found in summer off Oregon (McDonald et al., 1995; Green et al.[75]) and in summer and autumn in Shelikof Strait (north of Kodiak Island, Alaska) and the Gulf of Alaska (Brueggeman et al.[79]). The Gulf of California is inhabited year-round by fin whales, with a peak in abundance during winter and spring (Tershy et al., 1993; Silber et al., 1994). Whether fin whales found off southern and central California during summer migrate to the Gulf of California for winter awaits further investigation (Barlow et al., 1997). In low latitudes of the eastern tropical Pacific, fin whales are scarce in summer and winter (Lee, 1993; Wade and Gerrodette, 1993).

Three stocks have been designated in U.S. waters of the North Pacific for stock assessment and management purposes: 1) California/Oregon/Washington, 2) Alaska, and 3) Hawaii (Barlow et al., 1997; Hill et al., 1997). Around Hawaii, the fin whale is rarely sighted (Shallenberger[80]; Balcomb[81]), but acoustic recordings off Oahu and Midway Islands suggested a migration into Hawaiian (U.S. EEZ) waters in autumn and winter (Thompson and Friedl, 1982).

North Atlantic

In 1976, the IWC identified seven stock areas in the North Atlantic (Donovan, 1991) based on "statistical convenience" and history of exploitation (Fig. 28):

[78] Dohl, T. P., R. C. Guess, M. L. Duman, and R. C. Helm. 1983. Cetaceans of central and northern California, 1980-83: Status, abundance and distribution. Contr. 14-12-0001-29090. Final rep. to Minerals Manage. Serv., 284 p.

[79] Brueggeman, J., G. A. Green, K. C. Balcomb, C. E. Bowlby, R. A. Grotefendt, K. T. Briggs, M. L. Bonnell, R. G. Ford, D. H. Varoujean, D. Heinemann, and D. G. Chapman. 1990. Oregon-Washington marine mammal and seabird survey: Information synthesis and hypothesis formulation. Prep. for U.S. Dep. Inter., OCS Study MMS 89-0030.

[80] Shallenberger, E. W. 1981. The status of Hawaiian cetaceans. Rep. MMC-77/23 prep. for Mar. Mammal. Comm., Contr. MM7AC/28, 79 p.

[81] Balcomb, K. C. 1987. The whales of Hawaii, including all species of marine mammals in Hawaiian and adjacent waters. Marine Mammal Fund, San Francisco, Calif., 99 p.

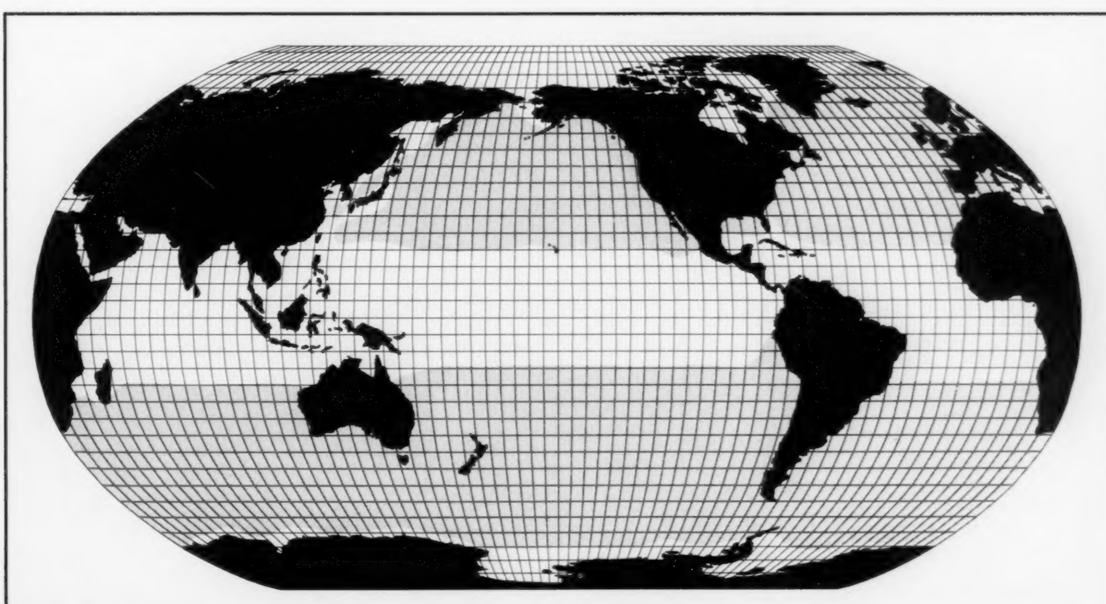


Figure 27.—Worldwide fin whale distribution. Adapted from Mizroch et al. (1984b).

A fin whale breaking the surface. Note the white coloration on the lower lip. S. Kraus, NMML Collection.

Figure 28.—North Atlantic fin whale stock boundaries recognized by the IWC (Donovan, 1991).

1) North Norway,
2) West Norway-Faroe Islands,
3) British Isles-Spain and Portugal,
4) East Greenland-Iceland,
5) West Greenland,
6) Newfoundland-Labrador, and
7) Nova Scotia.

In 1991, during the Special Meeting on the Comprehensive Assessment of North Atlantic Fin Whales, the IWC's Scientific Committee adopted alternative stock boundaries, which relate to historic catch areas and may be useful for assessing population abundance (IWC, 1992b; Butterworth and Punt, 1992). However, these suggested boundaries were not considered representative of biological stocks by the Scientific Committee (IWC, 1992b).

Underwater listening systems (part of the IUSS) have demonstrated that the fin whale is the most acoustically common whale species heard in the North Atlantic (Clark, 1995). They are acoustically detected year-round in the Norwegian Sea, and vocalizations show a sea-

sonal shift in which whales move southward during autumn and northward during spring in this region. The IUSS tracked fin whales during seasonal migrations along both the western and eastern Atlantic. The autumn southward migration pattern in the western North Atlantic was from Newfoundland-Labrador, past Bermuda, and into the West Indies, while in the eastern North Atlantic, the pattern was from the British Isles to the coasts of Spain and Gibraltar (Fig. 6, 7) (Clark, 1995).

In U.S. waters of the North Atlantic, the NMFS has recently designated one stock of fin whale (Waring et al., 1998). The fin whale is common from Cape Hatteras northward (Fig. 6), where the species accounted for 46% of all large whales and 24% of all cetaceans sighted over the continental shelf between Cape Hatteras and Nova Scotia during 1978–82 aerial surveys (Waring et al., 1998). The single most important area for this species appeared to be from the Great South Channel, along the 50 m isobath past Cape Cod, over Stellwagen Bank, and past Cape Ann to Jeffreys Ledge (Hain et al., 1992). Fin whales in this region are the dominant cetacean species and therefore most likely have the largest impact on the ecosystem of any cetacean (Hain et al., 1992).

Photoidentification studies in western North Atlantic feeding areas, particularly in Massachusetts Bay, have shown a high rate of annual return by fin whales, both within years (49%) and between years (45%) (Seipt et al., 1990). This apparent site-fidelity may be similar to matrilineally directed site-fidelity in humpback whales (Seipt et al., 1990; Clapham and Seipt, 1991; Agler et al., 1993). Evidence regarding where the majority of fin whales winter, calve, and mate is still scarce. Neonate strandings between October and January along the U.S. mid Atlantic coast suggest the possibility of an offshore calving area (Hain et al., 1992).

Southern Hemisphere

The IWC has divided the Southern Oceans into six baleen whale stock areas (Fig. 9) (Donovan, 1991). These areas may loosely correspond to fin whale stocks, but there is still insufficient distributional data on where these whales breed to validate this designation (IWC, 1992b).

Current and Historical Abundance

North Pacific

The most current (1991) population estimate for the entire North Pacific is between 14,620 and 18,630 based on history of catches and trends in CPUE[22] (Braham[3]). Prior to exploitation, there were an estimated 42,000–45,000 fin whales in the entire North Pacific (Ohsumi and Wada, 1974). In the early 1970's, this entire North Pacific population had been reduced to between 13,620 and 18,630 fin whales (Ohsumi and Wada, 1974).

The most recent data from 1991, 1993, and 1996 line-transect surveys of waters off California, Washington, and Oregon yielded an estimated current population abundance of 1,236 (CV = 0.20) fin whales (Barlow[74]). In Alaska, a survey in August 1994, covering 2,050 n.mi of track-line south of the Aleutian Islands, reported only four fin whale groups in this area (Forney and Brownell[68]). No abundance estimates could be calculated for Alaska waters from these sparse data. Also, there is no current abundance estimate available for Hawaiian waters. During the early 1970's, an estimated 8,520–10,970 fin whales occured in the eastern half of the North Pacific (Braham[3]).

If the estimates from the 1970's and 1991 (Ohsumi and Wada, 1974; Braham[3]) are accurate, no increase in fin whale numbers has occurred in the past 20 years despite an IWC ban on whaling in the North Pacific.

North Atlantic

There is no current estimate for the entire North Atlantic, but each IWC stock area, with the exception of North Norway, has a tentative estimate (Table 13). In the years before exploitation, there were an estimated 30,000-50,000 whales in the entire North Atlantic, and in the decade 1960–70, this population was estimated to number approximately 31,320 whales (Sergeant, 1977).

The most current (1991) population estimate for the western North Atlantic is between 3,590 and 6,300 fin whales based on the catch history and trends in CPUE[22] (Braham[3]). Waring et al. (1998) considered 1,700 (CV = 0.59) fin whales to be the minimum population estimate (N_{min}) for an area from the northern Gulf of Maine to the lower Bay of Fundy (Nova Scotia stock) based on line-transect surveys in July through September 1991–92. For the British Isles/Spain and Portugal stock, Braham[3] provided in 1991 an initial, preexploitation population estimate of 10,500 (95% C.I. 9,600–11,400) fin whales.

Southern Hemisphere

In the Southern Oceans, the most current (1979) population estimate is 85,200 (no CV) fin whales based on the history of catches and trends in CPUE[22] (IWC, 1979). In addition, 15,178 whales (no CV given and uncorrected for probability of sighting) were estimated to occur within surveyed areas south of lat. 30°S by combining data from JSV and IWC/IDCR 1978–88 ship-based surveys (IWC, 1996a). Prior to commercial exploitation these southern stocks were estimated to contain 400,000 fin whales (IWC, 1979).

Historic Exploitation Patterns

As early as the mid-17th century, the Japanese were capturing fin, blue, and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen, 1982; Cherfas, 1989). In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. The North Pacific and Antarctic whaling operations soon added this modern equipment to their arsenal (Tønnessen and Johnsen, 1982). After blue whales were depleted in most areas, the smaller fin whale became the focus of operations. Worldwide, fin whales were severely depleted by commercial whaling activities; over 700,000 were landed in the 20th century (Cherfas, 1989).

North Pacific

In the early Japanese nearshore net fisheries, 480 fin whales were taken from the mid 1600's to 1913 (Omura, 1986). Between 1914 and 1975, over 26,040 fin whales were caught through-

Table 13.—Current abundance estimates of North Atlantic fin whale stocks (N.e. = no published estimate; no data for North Norway stock).

IWC stock designation	Abundance estimate	Coefficient of variation	95% C.I.	Source[1]
Nova Scotia Stock (U.S. territory):				
Cape Hatteras, NC to Nova Scotia	4,680 (spring & summer)	0.23	N.e.	CeTAP[70]
Cape Hatteras, NC to Nova Scotia	194 (summer)	0.18	N.e.	Anonymous[7]
Cape Hatteras, NC to Nova Scotia	529 (summer)	0.19	N.e.	Anonymous[7]
Cape Hatteras, NC to Georges Bank	35 (summer)	0.56	N.e.	Waring et al., 1992
Northern Gulf of Maine and Bay of Fundy	2,700 (summer)	0.59	N.e.	Waring et al., 1998
Newfoundland/Labrador Stock[2]	13,253	1.42	N.e.	IWC, 1992c
West Greenland Stock[3]	178	N.e.	26–382	Larsen, 1995
East Greenland/Iceland Stock	11,563	0.261	N.e.	Gunnlaugsson and Sigurjónsson, 1990
British Isles/Spain and Portugal Stock[4]	17,355	0.266	10,400–28,900	Buckland et al., 1992
British Isles/Spain and Portugal Stock[4]	7,507	0.150	5,600–10,100	Goujon et al., 1995
British Isles/Spain and Portugal Stock	4,485	N.e.	3,369–5,600	Braham[3]

[1] Source footnote numbers refer to text footnote numbers.
[2] From 1965 to 1972 mark-recapture analyses.
[3] Excludes areas of high density from previous surveys.
[4] The 17,355 estimate covered 415,290 n.mi of trackline; the 7,507 estimate covered 204,929 n.mi of trackline.

out the North Pacific (Braham[3]). The Japanese fishery for fin whales peaked in 1914 when 1,040 whales were captured, and thereafter declined to between 300 and 400 whales per year until World War II. After World War II, the fin whale fishery was never as successful due to the scarcity of animals, and in 1975 the IWC banned fin whale hunting in the western North Pacific.

Along the west coast of North America, some fin whales were taken off California, British Columbia, and Alaska (Fig. 29), but this hunt ceased by 1972. In the rest of the North Pacific and the Bering Sea, catches dropped after the mid 1960's. The IWC issued a ban on commercial whaling for fin whales throughout the North Pacific in 1976.

North Atlantic

Over 48,000 whales were taken throughout the North Atlantic between 1860 and 1970 (Braham[3]). Fisheries existed off Newfoundland, Nova Scotia, Norway, Iceland, the Faeroe Islands, Svalbard (Spitsbergen), the islands off the British coasts, Spain, and Portugal (Fig. 6, 7, 18). These whales were rarely taken in U.S. waters, except when they ventured near the shores of Provincetown, Mass., during the late 1800's (Clark, 1887; True, 1904).

The fin whale fishery off Spain and Portugal began in 1921, but it took only 7 years for the local stocks to be depleted to the point of being economically unsuitable for further exploitation. Still, fin whaling resumed in the 1950's off northwest Spain where, from 1954 to 1987, a few hundred fin whales were caught each year (Aguilar and Lens, 1981; Sanpera and Aguilar[82]).

Southern Hemisphere

From 1904 to 1975, there were 703,693 fin whales taken in Antarctic whaling operations (IWC, 1990). Whaling in the Southern Oceans originally targeted humpback whales, but by 1913 this target species became rare, and the catch of fin and blue whales began to increase (Mizroch et al., 1984b). From 1911 to 1924, there were 2,000–5,000 fin whales taken per year. After the introduction of factory whaling ships in 1925, the number of whales taken per year increased substantially. From 1931 to 1972, approximately 511,574 fin whales were caught (Kawamura, 1994). In 1937 alone, over 28,000 fin whales were taken. From 1953 to 1961, the number of fin whales taken per year continued to average around 25,000. In 1962, sei whale catches began to increase as fin whales became scarce. By 1974, less than 1,000 fin whales were being caught per year. The IWC prohibited the taking of fin whales from the Southern Hemisphere in 1976.

Recently released Soviet whaling records indicate a discrepancy between reported and actual fin whale catch numbers by the U.S.S.R. in southern waters between 1947 and 1980 (Zemsky et al., 1995). The U.S.S.R. previously reported 52,931 whales caught, whereas the new data indicates that only 41,984 were taken. One reason for this discrepancy may lie in the mistaken identification of sei whales as fin whales in the original reporting.

Current Exploitation

From 1988 to 1995, there have been 239 reported kills of fin whales from the North Atlantic (Table 10). There is currently a "subsistence"[34] take of fin whales from the West Greenland stock. The IWC set a catch limit of 19 whales for the years 1995, 1996, and 1997 in West Greenland. All other fin whale stocks had a zero catch limit for those same years (IWC, 1995b). However, Iceland (East Greenland/Iceland stock) reported a catch of 136 fin whales in the 1988/89–1989/90 seasons, but has since ceased reporting fin whale kills to the IWC. Butterworth and Punt (1992) have suggested that a catch of 100 whales per year from this East Greenland/Iceland stock would be a sustainable mortality level.

[82] Sanpera, C., and A. Aguilar. 1984. Historical review of catch statistics in Atlantic waters off the Iberian Peninsula, 23 p. Unpubl. doc. SC/36/014 submitted to Rep. Int. Whal. Comm.

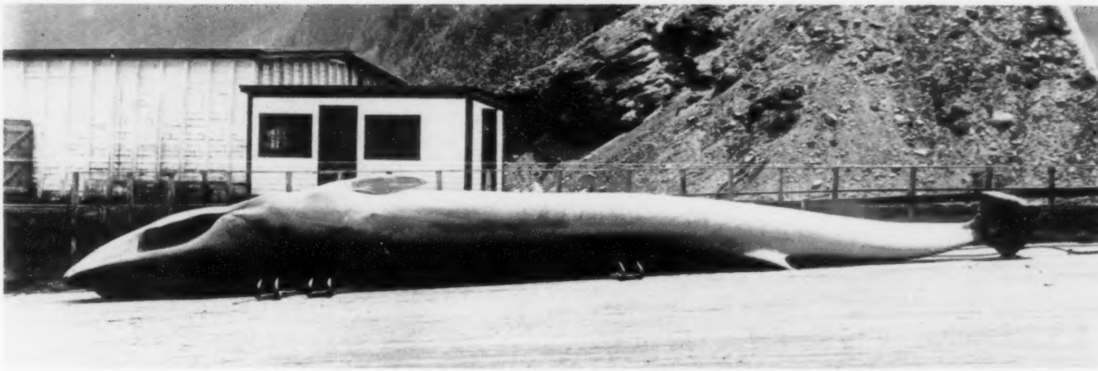


Figure 29.—Fin whale on flensing platform. Note the bicolored baleen plates. University of Washington Special Collections, Lagen Collection, negative UW1611.

Life History and Ecology

Feeding

Fin whales spend the summer feeding in the relatively high latitudes of both hemispheres, particularly along the cold eastern boundary currents in the North Pacific and North Atlantic Oceans and in Antarctic waters of the Southern Hemisphere. They are most abundant in offshore waters where their primary prey (e.g. euphausiids) is concentrated in dense shoals.

Fin whales may have a significant impact on marine ecosystems. As an example, the total annual (spring and summer) prey consumption by fin whales along the northeast U.S. continental shelf has been estimated at 664,000 tons per year (Hain et al., 1992). By biomass, fin whales in this area probably consume more food than any other cetacean species. It is assumed that fin whales undergo a partial or complete fast while traveling to lower latitudes in the fall and throughout the winter (Mizroch et al., 1984b).

The predominant prey of fin whales varies greatly in different geographical areas depending on what is locally abundant (IWC, 1992a). For instance, in the Northern Hemisphere they consume schooling fishes, such as capelin, *Mallotus villosus;* anchovies, *Engraulis mordax*; herring, *Clupea harengus;* and sandlance, *Ammodytes* spp. (Mitchell, 1975a; Overholtz and Nicolas, 1979; Kawamura, 1982; CeTAP[70]). Thus, they may be less prey selective than blue, humpback, and right whales. However, fin whales do depend to a large extent on the small euphausiids and other zooplankton species. In the Antarctic, they feed on krill, *Euphausia superba*, which occurs in dense near-surface schools (Nemoto, 1959). In the North Pacific, *E. pacifica*, *Thysanoessa inermis*, *T. longipes*, and *T. spinifera* are the primary prey items. In the North Atlantic, *Meganyctiphanes norvegica* and *T. inermis* are consumed (Nemoto,1959).

There is some speculation, because of the sharing of the Antarctic krill resource between both whale and nonwhale predators, that interspecific competition may be a critical factor in the biology of Southern Hemisphere fin whales (IWC, 1992a). However, there is no direct information on how such ecosystem level interactions may or may not affect the status of baleen whales (Kawamura, 1994; Clapham and Brownell, 1996; Clapham and Brownell[6]). Murphy et al. (1988) and Fraser et al. (1992) suggest that competition among whales and other small krill predators in the Antarctic ecosystem is relatively low.

Reproduction

Age at sexual maturity for both sexes ranges from 5 to 15 years (Lockyer, 1972). The average length at sexual maturity for both males and females is approximately 17.2 m (Mitchell, 1974a; Lockyer and Brown, 1979; Ratnaswamy and Winn, 1993). Conception occurs during a 5-month winter period in either hemisphere. After a 12-month gestation period, a single 6 m calf is born (Mizroch et al., 1984b). Between 6 and 11 months after birth, and at a length of 12 m, the immature fin whale is weaned (Best, 1966; Gambell, 1985). The mean calving interval for fin whales is 2.7 years, with a range of between 2 and 3 years (Agler et al., 1993).

Natural Mortality

The causes of natural mortality in fin whales are poorly understood. Despite harboring many endoparasites, it is only the giant nematode, *Crassicauda boopis*, that appears to be pathogenic (Lambertsen, 1986; 1992). The inflammation of the renal arteries and potential kidney failure, which infestations of *C. boopis* cause, may be a factor in limiting the recovery of some fin whale stocks (Lambertsen, 1992).

Presumably killer whales rarely prey on fin whales. If such attacks do occur, they likely go undetected by humans, thus accounting for the scarcity of information. Immature, ill, or very old individuals may be subject to mortality or serious injury from either killer whale or shark attacks under certain circumstances.

Estimated annual rates of natural mortality are higher in mature females than mature males (Aguilar and Lockyer,

1987; Lockyer and Sigurjónsson[83]). Reasons for this are speculative, but may be due to reproductive stresses (Aguilar and Lockyer, 1987). The generally accepted natural mortality rate for adult fin whales is 4%, with a range of 4–6% (Clark, 1982; de la Mare, 1985). This rate may be higher in immature individuals of both sexes.

Human-related Mortality

Fisheries Interactions

There are no reports of fisheries-related fin whale mortality in the North Pacific (Hill et al., 1997). However, Barlow et al. (1997) noted that a conflict may exist in the offshore drift gillnet fishery in California and Mexico. Serious injury or mortality caused by entanglement in fishing gear may go undetected if fin whales swim away carrying portions of the gear or if entanglements occur far from shore. However, fishermen report that large blue and fin whales usually break through nets without entangling and with very little damage to the net (Barlow et al., 1997).

In U.S. North Atlantic waters, there were no reported mortalities from fisheries activities from 1989 to 1993, but an entanglement database maintained by the NMFS Northeast Regional Office from 1975 to 1992 includes nine occasions of fishing gear entanglement. Two of these entanglements resulted in known death to the whales, five of the whales were recorded trailing fishing line of an unspecified source, and three were entangled in lobster-pot line (Blaylock et al., 1995). In a review of 1992–96 data from this same NMFS database, an additional three whales had net and rope marks or had line wrapped around mouth and tail, suggesting fishery interactions (Waring et al., 1998). The total mortality and serious injury from North Atlantic fisheries-related incidents is considered biologically insignificant with regard to their estimated PBR level[37] (3.4 whales per year, Waring et al., 1998), but the full range of fisheries that may interact with fin whales have not been thoroughly investigated (Blaylock et al.,1995).

One concern is the potential impact of overexploitation of fish stocks by commercial fishery operations in the North Atlantic. Fin whales are an integral part of the North Atlantic ecosystem (Hain et al., 1992), and several fish species taken in commercial fisheries are also fin whale prey (e.g. herring, mackerel, etc.). Conversely, fin whales were implicated in the decline of herring stocks on Georges Bank in the middle and late 1970's (Sissenwine et al., 1984).

Vessel Collisions

It is possible that ship strikes affect all fin whale stocks, but because of their pelagic nature, they go unreported because injured or killed animals do not strand. In U.S. waters of the North Pacific, one death due to ship collision was reported in 1991 (Barlow et al., 1997). In U.S. waters of the North Atlantic, there are nine records of ship collisions, boat strikes, or propeller scars between 1980 and 1994 (Blaylock et al., 1995) and four such records between 1991 and 1995 (Waring et al., 1998). In 1996, one anecdotal incident was reported from the southeastern United States of a whale being hit at sea by a container ship and carried into harbor on the ship's bow (Kreuger, 1996).

Noise Disturbance

Studies have shown that fin whales respond to noise created by approaching vessel traffic in a variety of ways, depending on the behavior of the animals at the time of approach and the speed and direction of the approaching vessel. Fin whales involved in feeding react less rapidly and with less obvious avoidance maneuvers than those not involved in feeding (Richardson et al., 1995). In the St. Lawrence River estuary, summering fin whales encounter heavy recreational and commercial vessel traffic from several sources (i.e. industrial freight, whale watching). In the St. Lawrence River, the most marked reactions to these vessels occurred when boats made fast, erratic approaches or sudden changes in direction or speed (Edds and MacFarlane, 1987; MacFarlane[77]). In the waters off New England, an area in which there is a high level of whale watching and recreational boat activity, fin whales have been reported to reduce the duration of their surfacing and to reduce the number of blows per surfacing when whale-watching and other vessels are nearby (Stone et al., 1992; Young[84]). However, there is also evidence of habituation to increased vessel traffic by the fin whales in these waters (Watkins, 1986).

Noise disturbance from seismic exploration appears not to affect fin whales in detectable ways. Noise pulses from air guns off Oregon did not result in a change in fin whale vocalization rates when compared to periods prior to the onset of noise, suggesting they were undisturbed by the pulses (McDonald et al., 1993)

Classification Status

The fin whale was listed as endangered under the ESA in 1973 and is protected under the MMPA. Endangered status is applied to all stocks in U.S. waters (Anonymous, 1994a). Internationally, the North Pacific, Nova Scotia, West Norway/Faeroe Islands, and Southern Hemisphere stocks are classified as "Protected Stocks" by the IWC. Under this designation, the IWC recognized that these whales are 10% or more below their maximum sustainable yield (MSY) levels, and therefore commercial whaling is prohibited (IWC, 1995b). The East Greenland/Iceland stock is classified as a "Sustained Management Stock" (SMS) by the IWC. This SMS designation indicates these whales are not more than 10% below and not more than 20% above their MSY levels. Whaling is permitted under this classification under advice of the Scientific Committee and in the absence of a moratorium on whaling (IWC, 1995b). The remaining stocks—West Greenland, Newfoundland/Labrador, British Isles/Spain and Portugal,

[83] Lockyer, C., and J. Sigurjónsson. 1992. Author's summary of SC/F91/F8: The Icelandic fin whale, (*Balaenoptera physalus*): biological parameters and their trends over time. Annex F. Rep. Int. Whal. Comm. 42:617-618.

[84] Young, N. M. 1989. Dive and ventilation patterns correlated to behavior of fin whales, *Balaenoptera physalus*, in Cape Cod and Massachusetts Bays (Abstr.). *In* Proceedings of the Eighth Biennial Conference on the Biology Marine Mammal, Dec. 1989, Pacific Grove, Calif.

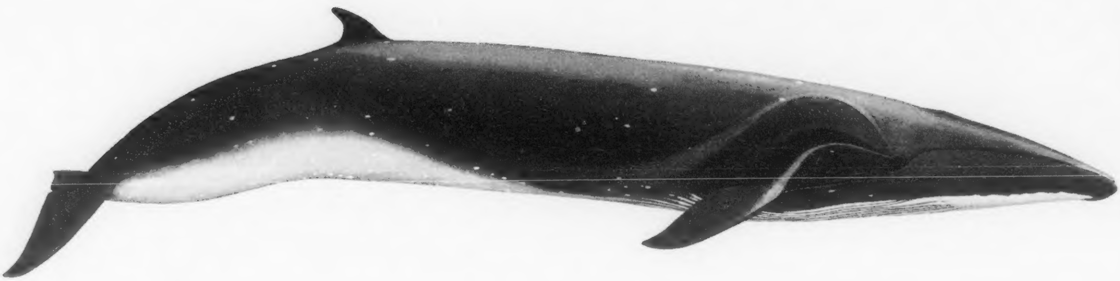
Table 14.—Factors possibly influencing the recovery of North Atlantic fin whale stocks under the ESA (1973) §4(a)(1), 1992 Amend. (Southern Hemisphere data are not available).

Factor	North Pacific	Western North Atlantic[1]	Eastern North Atlantic[2]
1. Present or threatened destruction or modification of habitat	Offshore oil and gas development	Unknown	Unknown
2. Overutilization for commercial, subsistence, recreational, scientific, or educational purposes	Unknown	Whale watching, scientific research, photography, and associated vessel traffic; West Greenland harvest	Icelandic harvest
3. Disease or predation	Unknown	Giant nematode, *C. boopis*, infestations	Giant nematode, *C. boopis*, infestations
4. Other natural or man-made factors	Vessel collisions	Vessel collisions; incidental take (e.g. gillnets, lobster pots, seines, fish weirs); human depletion of fish stocks	Unknown

[1] Nova Scotia, Newfoundland/Labrador, West Greenland.
[2] East Greenland/Iceland, North Norway, British Isles/Spain and Portugal.

and North Norway—have no formal IWC classification; however, their catch limits will remain at zero as long as the current moratorium on commercial whaling is in place.

Since Braham's 1991 status review[3], there has been little additional information regarding fin whale abundance or stock identity. The factors possibly affecting the status of fin whales are summarized in Table 14. At this time, any reevaluation of fin whale status awaits the collection of more reliable information on stock structure, distribution and migration patterns, trends in abundance, causes of mortality, and factors influencing the recovery of fin whale stocks, as well as the development of objective delisting criteria. A joint Recovery Plan has been developed for both fin and sei whales (Anonymous[7]). This plan attempts to outline steps towards recovery of the fin whale through focused research priorities designed to increase our understanding of current threats, alleviate the possibility of future threats, and encourage international cooperation.



The Sei Whale

Introduction

The sei whale, *Balaenoptera borealis* Lesson 1828, is the third largest member of the family Balaenopteridae, following the blue, *B. musculus*; and fin, *B. physalus*, whales. At maturity, sei whales range from 12 to 18 m in length (Lockyer, 1977; Martin, 1983). Their coloration is gray, with a variable white region from the chin to the umbilicus. The undersides and sides of the whale may appear mottled, with gray or white circular scars caused by ectoparasitic copepods, *Penella* spp. (Andrews, 1916; Ivashin and Golubovsky, 1978), lampreys (Pike, 1951; Rice, 1977a), or cookiecutter sharks, *Isistius brasiliensis* (Shevchenko, 1977). The dorsal fin is generally tall, slender, and—compared to the blue and fin whale—further forward on the body (Fig. 30).

The sei whale is usually found alone or in small groups, and the species appears to have no well-defined social structure. Like other balaenopterids, they have fringed baleen plates instead of teeth and ventral grooves which expand to allow for engulfing large quantities of water during feeding on small zooplankton. Mead (1977) noted that sei whale baleen is much finer than that of other *Balaenoptera* species and is a reliable feature for species identification.

Distribution and Migration

Sei whales are found in all oceans (Fig. 31). These whales migrate long distances from high-latitude summer feeding areas to relatively low-latitude winter breeding areas. For the most part, the location of these winter areas remains a mystery. Compared to other balaenopterids, sei whales appear restricted to the more temperate waters and occur within a smaller range of latitudes (Mizroch et al., 1984c). They do not associate with coastal features, but instead they are found in deeper waters associated with the continental shelf edge (Hain et al., 1985). There is some evidence from catch data of differential migration patterns by reproductive class, whereby females arrive at and depart from feeding areas earlier than males (Matthews, 1938; Gambell, 1968).

North Pacific

The IWC's Scientific Committee has designated the entire North Pacific Ocean as one sei whale stock unit (Donovan, 1991). However, mark-recapture studies using Discovery tag[38] and catch distribution data, as well as comparisons of morphology, indicate that more than one stock exists: one between long. 175°W and 155°W and another east of long. 155°W (Fig. 4, 5) (Masaki, 1976, 1977). During winter, sei whales are found from lat. 20° to 23°N and during the summer from lat. 35° to 50°N (Masaki, 1976, 1977). Horwood (1987) reported that 75–85% of the total North Pacific population of sei whales resides east of long. 180°W.

Within the U.S.EEZ[69] there is a significant lack of information regarding the distribution of sei whales in the eastern North Pacific (Barlow et al., 1997). Two whales tagged off California were later captured off Washington and British Columbia, revealing a possible link between these two areas (Rice, 1974). However, the lack of other tag recovery data makes these two cases inconclusive.

North Atlantic

The IWC recognizes three sei whale stocks in the North Atlantic (Fig. 32):

1) Nova Scotia,
2) Iceland-Denmark Strait, and
3) Northeast Atlantic.

However, the IWC noted that identification of sei whale stocks is very difficult, and that these three stocks are based on regions of past whaling operations, as opposed to biological information (Donovan, 1991). Mitchell and Chapman (1977) noted another possible stock boundary separating the Nova Scotia stock from sei whales off northeast Newfoundland and Labrador based on catch data, tag recoveries, and known migration patterns. In the northwest Atlantic, whales travel along the eastern Canadian coast in autumn, June, and July on their way to and from the Gulf of Maine and Georges Bank, where they occur in winter and spring (Mitchell, 1975b; Blaylock et al., 1995). Peak abundance in U.S. waters occurs in spring along eastern Georges Bank, into the Northeast Channel, and along the southwest edge of Georges Bank in the area of Hydrographer Canyon (CeTAP[70]). In years of copepod abundance, more whales are found inshore of these areas, such as in the Great South Channel, on Stellwagen Bank, and in the Gulf of Maine (Payne et al., 1990; Schilling et al., 1992).

In the northeast Atlantic, sei whales winter south of Spain, move to the Spanish, Portuguese, and western Ireland coasts in early spring, to the northwest of the Shetland Islands, off the

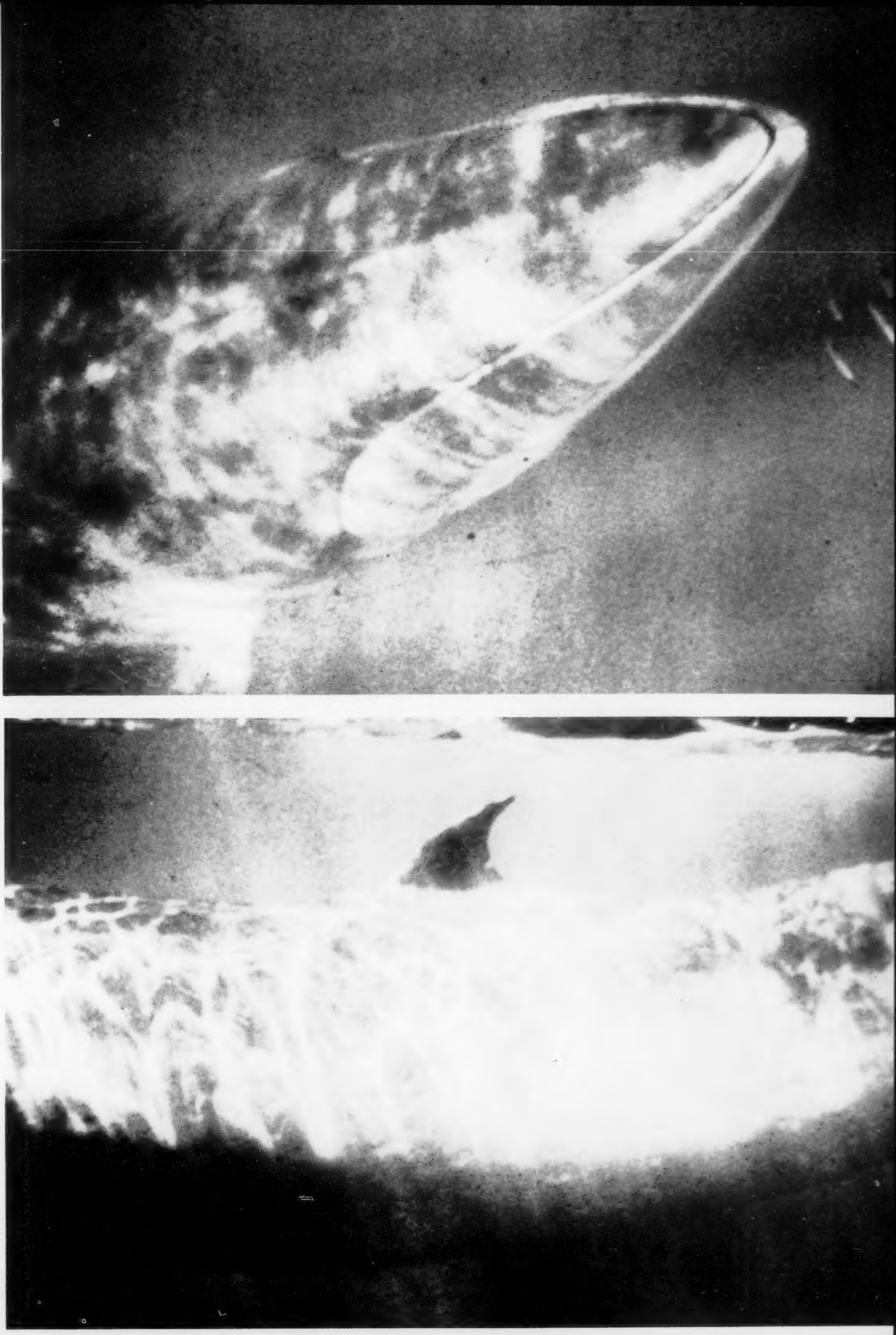


Figure 30.—Underwater views of a sei whale. G. Williamson, NMML Collection.

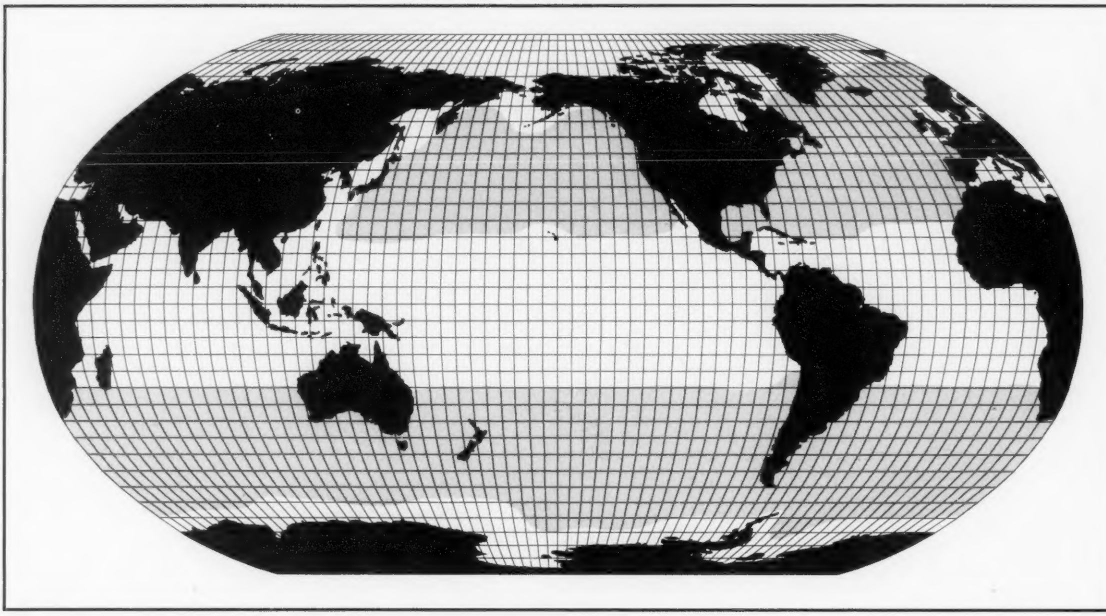


Figure 31.—Worldwide sei whale distribution. Adapted from Mizroch et al. (1984c).

Figure 32.—North Atlantic sei whale stock boundaries recognized by the IWC (Donovan, 1991).

Hebrides, and west Norway in April through May, and summer off north Norway, west Norway, the Shetland Islands, the Hebrides, and the Faeroe Islands (Fig. 7) (Ingebrigtsen, 1929). Occasionally, sei whales are found as far north as Bear Island and Spitsbergen (about lat. 72°N) (Fig. 18) (Jonsgård, 1966).

Southern Hemisphere

The IWC recognizes six sei whale stock areas in the Southern Ocean (Fig. 9) (Donovan, 1991). In general, Antarctic austral summer distribution based on historic catch data is from lat. 40° to 50°S, while austral winter distribution is unknown (Mizroch et al., 1984c; Anonymous, 1994b). There is no conclusive evidence of potential wintering areas for any of these stocks, although Discovery tag[38] data from captured whales showed links between some regions (IWC, 1977). For instance, links were found between the Brazilian coast with the western half of Area II, the Natal Coast of South Africa with the eastern half of Area III and with the

western half of Area IV, and western and southeastern Australia with Area IV.

Current and Historical Abundance

North Pacific

The most current (1977) population estimate for the North Pacific Ocean is 9,110 (no CV) based on the history of catches and trends in CPUE[22] (Tillman, 1977; Braham[3]). There are no estimates of abundance for this ocean based on aerial or ship sighting surveys. In California waters, there were only one confirmed and five possible sei whale sightings from 1991, 1992, and 1993 aerial and ship surveys (Hill and Barlow, 1992; Carretta and Forney, 1993; Mangels and Gerrodette, 1994). There were no confirmed sightings off Washington and Oregon during recent aerial surveys (Green et al.[75]).

Prior to commercial whaling in the North Pacific (late 1800's to early 1900's), there were an estimated 42,000 sei whales (Tillman, 1977). By the end of the period of exploitation (1974), their numbers had been reduced to between 7,260 and 12,620 (no CV) (Tillman, 1977).

North Atlantic

The most current (1991) population estimate for the entire North Atlantic Ocean based on the history of catches and trends in CPUE[22] is 4,000 (no CV) (Braham[3]). This low-precision estimate is not considered a true index of abundance (Blaylock et al., 1995). The most recent estimates for the Iceland/Denmark Strait stock are 1,290 (CV = 0.603) whales from ship-based surveys in 1987 and 1,590 (no CV) whales from ship-based surveys in 1989 (Cattanach et al., 1993). Based on data from Discovery tag[38] studies, Mitchell and Chapman (1977) provided a population estimate for the Nova Scotia stock of between 1,393 and 2,248 whales, with a minimum estimate of 870 for this stock. Estimates in U.S. waters (Nova Scotia stock), derived from the Cetacean and Turtle Assessment Program (CeTAP) data[70] in 1982, are not considered statistically reliable because of low survey effort and inaccuracy in accounting for submerged animals (Blaylock et al., 1995). No sei whales were sighted during a more recent (August through October 1991) aerial survey conducted during the CeTAP study.

There is no information on the initial abundance of sei whales in the North Atlantic prior to commercial whaling. But, in 1966, there were an estimated 1,856 whales in the Nova Scotia stock and 828 whales in the Labrador Sea (Mitchell, 1974a).

Southern Hemisphere

Based on the history of catches and trends in CPUE[22], current sei whale abundance estimates range from 9,800 to 12,000 whales in the Southern Oceans (IWC, 1980b; Mizroch et al., 1984c; Braham[3]). The IWC reported an estimate of 9,718 whales (no CV) based on results of the 1978 through 1988 JSV and IWC/IDCR survey data (IWC, 1996a).

Braham[3] estimated that 65,000 sei whales occurred in the Southern Hemisphere prior to commercial whaling. Similarly, the IWC used catch data from the 1930's to estimate that 63,100 sei whales occurred prior to commercial whaling in the Southern Oceans (IWC, 1980b; Mizroch et al., 1984c).

Historic Exploitation Patterns

In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of some previously unobtainable large whale species. The North Pacific and Antarctic whaling operations soon added this modern equipment to their arsenal. After blue and fin whales were depleted in most areas, sei whales became the focus of operations. In the 1950's through 1970's, these whales were severely depleted by commercial whaling operations (Fig. 33).

North Pacific

From 1910 to 1975, approximately 74,215 sei whales were caught throughout the North Pacific Ocean (Horwood, 1987). From the beginning of the 20th century, Japanese whaling operations consisted of a large proportion of sei whales. In local waters off Japan, 300–600 sei whales were caught per year from 1911 to 1955. The Japanese sei whale catch peaked in 1959, when 1,340 whales were caught. In 1971, after a decade of high sei whale catch numbers, this species became scarce in Japanese waters. After 1975, sei whales became protected in the western North Pacific under IWC authority (Mizroch et al., 1984c).

Off the west coast of North America, sei whales were commercially hunted by Canadians in British Columbia from the late 1950's until the mid 1960's, when the number of whales captured dropped to around 14 individuals per year. Along the U.S. coast, shore-based whaling operations existed in California (Cherfas, 1989). After 1971, hunting of sei whales ceased in the eastern North Pacific.

North Atlantic

From 1885 through 1984, approximately 14,295 sei whales were taken in the North Atlantic Ocean (Horwood, 1987). These whales were first hunted off Norway during the late 1800's, where they became the target species in late summer, after the blue and fin whales had already migrated out of high latitude North Atlantic waters. And, as the stocks of blue and fin whales became scarce, sei whale catches gained importance in this region (Mizroch et al., 1984c). Sei whales were originally hunted only off Norway and Iceland, but from 1967 through 1972, sei whales were also taken off Nova Scotia (Mitchell, 1975b).

Southern Hemisphere

A total of 152,233 sei whales were caught in the Southern Hemisphere from 1910 through 1979 (Horwood, 1987). Whaling in the Southern Oceans originally targeted humpback whales. By 1913, this target species had become rare and the catch of fin and blue whales began to increase. As these species likewise became scarce, sei whale catches increased rapidly in the late 1950's and early 1960's (Mizroch et al., 1984c). The catch peaked in 1964 at over 20,000 sei whales, but by 1976 this number dropped to below 2,000 and the species received IWC protection in 1977.

Recently revealed Soviet whaling catch data from the years 1947 through 1980 showed that over 17,000 more sei

whales were caught (total = 50,034) than were previously reported (33,001) to the IWC (Zemsky et al., 1995). One reason for this discrepancy may have been the misidentification of sei whales as fin whales in the original reporting.

Current Exploitation

From 1988 to 1995, there have been 12 reported takes of sei whales from the North Atlantic (Table 10). All of these takes were off Iceland and West Greenland. However, the IWC set a catch limit of zero for all stocks of sei whales beginning in 1985 (IWC, 1995b).

Life History and Ecology

Feeding

Sei whales spend the summer feeding in the relatively high latitudes of both hemispheres, particularly along the cold eastern currents of the North Pacific and North Atlantic Oceans and in the Antarctic waters of the Southern Hemisphere. They range farther offshore than fin whales in search of prey concentrations.

Sei whales are less prey-selective than fin whales. Sei whales consume primarily copepods, but they also prey on euphausiids and small schooling fishes when these species are locally abundant (Table 15) (Mizroch et al., 1984c). This species seems to have the greatest flexibility relative to other balaenopterids in their feeding strategies, using both "engulfing" and "skimming" to capture prey (Nemoto, 1959).

In the Southern Hemisphere, there is some evidence that sei whales may minimize direct interspecific competition with the blue, fin, and minke whales by foraging in warmer waters than do the latter species, by consuming a relatively wider variety of prey, and by arriving later on the feeding grounds than other baleen whales (Kawamura, 1978, 1980, 1994; IWC, 1992a). However, Murphy et al. (1988) and Fraser et al. (1992) suggested that competition among whales and other krill predators in the Antarctic is relatively low (Clapham and Brownell, 1996).

Reproduction

Sei whales reach sexual maturity between 5 and 15 years of age. Similar to the fin whale, conception occurs during a 5-month period in the winter of either hemisphere. After a gestation period of around 12 months, a calf measuring about 4.4 m is born. Between 6 and 9 months after birth, the immature whale is weaned at a length of 9 m. The calving interval for sei whales ranges from 2 to 3 years (Rice, 1977a; Lockyer and Martin, 1983; Mizroch et al., 1984c).

Natural Mortality

Information on natural mortality in sei whales is scant. The estimated an-

Figure 33.—A raft of harvested sei whales. NMML Collection.

nual natural mortality rate is around 7.5% (Allen, 1980). This mortality rate is relatively higher for fin and blue whales and may be even greater among immature sei whales. Endoparasitic helminths are commonly found in sei whales, and these infestations can result in pathogenic effects, especially when found in the liver and kidneys (Rice, 1977a). Mizroch et al. (1984c) mentioned an unknown disease affecting approximately 7% of the California sei whale population, which results in loss of baleen plates and could hinder feeding.

Sei whale predation by killer whales has not been reported. However, it is likely, given observations of killer whale attacks on fin, blue, and sperm whales, that killer whale attacks result in mortality or serious injury to immature or weakened individuals. If such attacks occur, they likely go undetected by humans. Although they have not been reported, shark attacks may also result in mortality or serious injury to vulnerable sei whales (e.g. the very young or old and the ill or injured).

Human-related Mortality

Fisheries Interactions

There have been no reports of sei whale mortality caused by fishing activities in any eastern North Pacific fishery. However, Barlow et al. (1997) noted that a conflict may exist in the offshore drift gillnet fishery. Potential injury or mortality in this fishery may go undetected because entangled sei whales may swim away carrying gear.

In U.S. waters of the North Atlantic, fisheries-related mortality or serious injury was not reported in commercial fishing activities from 1989 to 1995 (Blaylock et al., 1995; Barlow et al., 1997). Total mortality and serious injury from fisheries-related incidents is considered biologically insignificant, but a comprehensive review of all fisheries has not been done.

Vessel Collisions

It is possible that ship strikes affect all stocks of sei whales but, due to their pelagic nature, go unreported because the injured or killed animals do not strand. One death was documented in 1994, when a container ship arrived in Boston harbor with a sei whale carcass on its bow. The crew estimated that the whale had been struck approximately 4 days before the ship pulled into port (Waring et al., 1998).

Noise Disturbance

Although little is known of sei whale acoustic behavior, hearing thresholds, and tolerance of noise, they appear to respond to approaching vessel traffic in relatively the same manner as blue and fin whales. Responses to boats appear to depend on the behavior of the animals at the time of approach and the speed and direction of the approaching vessel. In general, however, sei whales exhibit more avoidance behavior than do fin whales when being approached by a vessel (Gunther, 1949).

Classification Status

The sei whale was listed as endangered under the ESA in 1973 and is protected under the MMPA. Endangered status is applied to all sei whale stocks in U.S. waters (Anonymous, 1994b). Internationally, an IWC "Protected Stock" classification has been assigned to the North Pacific, Nova Scotia, and Southern Hemisphere stocks by the Commission. Under this designation, the IWC recognizes that these stocks are 10% or more below their maximum sustainable yield (MSY) levels, and therefore commercial whaling is prohibited (IWC, 1995b). Two of the North Atlantic stocks, Iceland/Denmark Strait and Eastern North Atlantic, have no formal IWC classification; however, their catch limits will remain at zero until the Commission receives a comprehensive assessment of these stocks and until the

Table 15.—Sei whale prey items (Mizroch et al., 1984c).

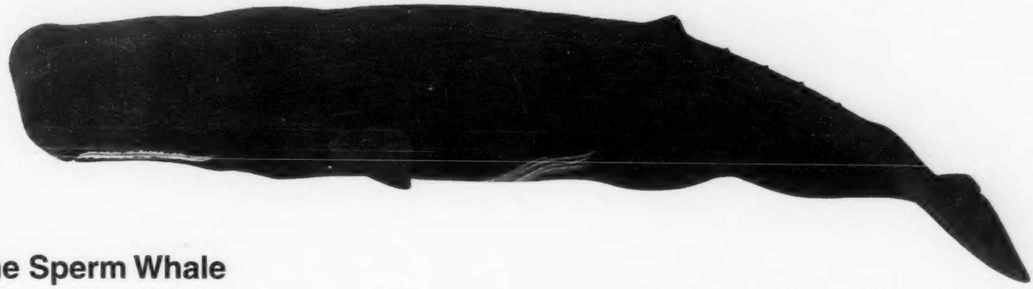
Region	Prey type	Species
Northern Hemisphere	Fish	*Engraulis* spp. (anchovies) *Cololabis* spp. (sauries) *Trachurus* spp. (jack mackerel)
North Pacific	Copepod	*Calanus cristatus* *C. plumchrus* *C. pacificus*
	Euphausid	*Euphausia pacifica* *Thysanoessa inermis* *T. longipes* *T. spinifera*
North Atlantic	Copepod Euphausid	*Calanus finmarchicus* *Meganyctiphanes norvegica* *Thysanoessa inermis*
Antarctic	Copepod	*Calanus tonsus* *C. simillimus* *Drepanopus pectinatus*
	Euphausid	*Euphausia superba* (Antarctic krill) *E. vallentini*

Table 16.—Factors possibly influencing the recovery of North Atlantic sei whale stocks under the ESA (1973) §4(a)(1), 1992 Amend. (Southern Hemisphere data is not available).

Factor	North Atlantic	North Pacific
1. Present or threatened destruction or modification of habitat	Unknown	Unknown
2. Overutilization for commercial, subsistence, recreational, scientific, or educational purposes	Icelandic harvest; whale watching, scientific research, photography, and associated vessel traffic	Whale watching, scientific research, photography, and associated vessel traffic
3. Disease or predation	Parasitic helminth infestations	Unknown
4. Other natural or man-made factors	Vessel collisions	Vessel collisions

current moratorium on commercial whaling is ended.

Since Braham's 1991 status review[3], there has been little advance in the accuracy and availability of population estimates or stock identity. The factors possibly influencing the status and recovery of sei whales are summarized in Table 16. At this time, any reevaluation of sei whale status awaits the collection of more reliable information on stock structure, distribution and migration patterns, trends in abundance, causes of mortality, and factors influencing the recovery of sei whale stocks, as well as the development of objective delisting criteria. A joint Recovery Plan has been developed for both sei and fin whales (Anonynous[7]). This plan attempts to outline steps towards recovery of the sei whale through focused research priorities designed to increase our understanding of sei whale biology, identify current threats to their survival, alleviate the possibility of future threats, and encourage international cooperation.



The Sperm Whale

Introduction

The sperm whale, *Physeter macrocephalus* Linnaeus, 1758[85], is the largest and most sexually dimorphic member of the odontoceti or toothed whales. Males reach a maximum length of 18.5 m, while the maximum length of females is 12.5 m (Odell, 1992). Calves at birth have an average length of 4 m. The most distinctive physical feature of the sperm whale is the exceptionally large head to body ratio: about one-third of the total body length. The enormous head contains a reservoir of spermaceti oil produced by the spermaceti organ. And a black or grayish fatty substance, known as ambergris, is produced in the sperm whale's intestines. Near the anterior of the head and to the left is a single blow hole (Fig. 34). The narrow bottom jaw holds 17–29 pairs of functional teeth that align with indentations in the upper jaw (Rice, 1989).

These toothed whales are rarely found in waters less than 300 m deep. They are often concentrated around oceanic islands in areas of upwelling and along the outer continental shelf and mid ocean waters (Rice, 1989).

Sperm whales are deep divers. Solitary adult males can stay submerged for over 60 minutes at recorded depths of over 2,000 m (Watkins et al., 1993). Mixed groups of females and young whales with calves have an average dive time of 8 minutes, while mixed groups without calves average 25 minutes (Leatherwood et al., 1982; Mano, 1990; Gordon and Steiner, 1992). Body size, degree of social cohesion, oceanographic features or bottom topography, and prey species availability are all factors that may affect variation in dive behavior between individuals and areas.

Distribution and Migration

Sperm whales inhabit all ocean basins, from equatorial waters to the polar regions. In general, their distribution varies by gender and age composition of groups and is related to prey availability and certain oceanic conditions (Fig. 35). Mature females, calves, and immature whales of both sexes are found in social groups in temperate and tropical waters year round. Very rarely are female/immature groups found higher than lat. 50°N and lat. 50°S (Reeves and Whitehead, 1997). Male sperm whales lead a mostly solitary life after reaching sexual maturity between 9 and 20 years of age and travel into regions as high as lat. 70°N in the North Atlantic and lat. 70°S in the Southern Ocean (Reeves and Whitehead, 1997).

General migration patterns vary between males and females. In summer, all sperm whales can be found at the highest latitudes of their range. In winter, female/immature groups migrate closer to equatorial waters in both hemispheres, possibly following warmer sea-surface temperatures (Kasuya and Miyashita, 1988; Waring et al., 1993). Sexually mature males join these female/immature groups throughout the winter. The genetic homogeneity of sperm whales worldwide, suggests that genetic exchange occurred between Northern and Southern Hemisphere populations at some time in their evolutionary history (Dufault et al.[86]).

Large-scale oceanographic events, such as El Niño, also seem to affect the distribution and movements of sperm whales (Whitehead et al.[87]), creating annual and seasonal geographic variability.

North Pacific

In 1981, the IWC's Scientific Committee designated two sperm whale stocks in the North Pacific, western and eastern, based on whaling records, the results of Discovery tagging[38], and the intermingling of males in the northern latitudes (Donovan, 1991). The boundary delineating western and eastern North Pacific stocks became known as the "Cambridge Line" (Fig. 36), and has been much debated since its acceptance by the IWC's Scientific Committee. There is evidence from historical whaling data, ship-based surveys, and oceanographic features, that three or more North Pacific stocks of sperm whales should be recognized for management purposes (Bannister and Mitchell, 1980; Kasuya, 1991).

Sperm whales occur throughout the North Pacific. Female and immature whales are found year round in temperate and tropical waters from the Equator to around lat. 45% N. During summer, mature male sperm whales are thought to move north into waters off the Aleutian Islands, Gulf of Alaska, and

[85] Both *Physeter macrocephalus* and *Physeter catodon* are scientific names used in the literature to refer to the sperm whale. However, *P. macrocephalus* has been designated as the preferred name by the International Code of Zoological Nomenclature's Article 24(a) naming procedure (Rice, 1998). *P. macrocephalus* has never been used to refer to another species, while *P. catadon* has been used in reference to other cetaceans (e.g. pilot whales) (see Husson and Holthius, 1974).

[86] Dufault, S., H. Whitehead, and M. Dillon. 1997. An examination of current knowledge on the stock structure of sperm whales (*Physeter macrocephalus*) world-wide. Unpubl. doc. SC/49/07 submitted to Rep. Int. Whal. Comm., 19 p.

[87] Whitehead, H., V. Papastavrou, and S. Smith. 1990. Sperm whales and El Niño off the Galapagos Islands. Unpubl. doc. SC/40/Sp4 submitted to Rep. Int. Whal. Comm., 6 p.

the southern Bering Sea (Fig. 4). However, Discovery tag[38] data revealed considerable east-west movement between Alaska and the western North Pacific, with little evidence of north-south movement in the eastern North Pacific (Ohsumi and Masaki, 1977; Wada, 1980; Taylor[88]).

In the U.S. EEZ of the North Pacific, three discrete population "centers" have been identified for stock assessment purposes: 1) Alaska, 2) California/Oregon/Washington, and 3) Hawaii (Barlow et al., 1997; Hill et al., 1997). These stock designations are based on distributional data from sightings and catches only, and there are no reliable phenotypic or genotypic data available for any of the sperm whale "centers" in U.S. waters (Small and DeMaster, 1995; Hill et al., 1997).

A survey conducted by the NMFS in the winter of 1997 (Sperm Whale Abundance and Population Structure, or SWAPS) was designed to census these three "centers" and the area south of the U.S./Mexican border to more clearly determine sperm whale distribution and abundance in this region. Preliminary results of this survey (new abundance estimates are still being determined) along with the results of previous surveys in the same area, suggest that seasonal sperm whale distribution in these waters varies annually, and brings into question the belief that sperm whales are abundant during February off central California (Bannister and Mitchell, 1980). More work is necessary in the temperate eastern Pacific before reliable stock structure designations can be made (Taylor[88]; Taylor et al.[89]).

Sperm whales in the western North Pacific stock occur from the Equator, along the Philippines, and up to the Kuril Islands and Kamchatka Peninsula, Russia (Fig. 5) (Kasuya and Miyashita, 1988; Shuntov, 1994). Based on Japanese coastal whaling data, tag returns, blood typing, and whale distribution associated with oceanographic current systems (i.e. Kuroshio Current and Oyashio Front), Kasuya (1991) proposed that there are three distinct sperm whale stocks in the North Pacific: 1) northwest North Pacific, 2) southwest North Pacific, and 3) eastern North Pacific. However, distinction between the three is confounded by the overlap in male distribution in northern latitudes (Kasuya and Miyashita, 1988).

North Atlantic

There is evidence from the harvest of Discovery tagged[38] individuals that North Atlantic sperm whales are one geographically continuous stock. One sperm whale tagged on the Scotian Shelf was killed over 7 years later off Spain (Mitchell, 1975c). From five to six handheld harpoons from the Azore sperm whale fishery were recovered from whales killed off northwest Spain (Donovan, 1991), with an additional Azorean harpoon recovered from a male sperm whale killed off Iceland (Fig. 7) (Martin, 1982). Consequently, the IWC recognized the North Atlantic sperm whale population as one management stock.

Figure 34.—Aerial view of an adult sperm whale. Note the angled blow. NMML Collection.

[88] Taylor, B. 1997. Appendix 3. *In* D. P. DeMaster (Editor), Minutes from fifth meeting of the Alaska Scientific Review Group, 7-9 May 1997, Seattle, Wash., 21 p. Avail. from D. P. DeMaster, Director, Natl. Mar. Mammal Lab., 7600 Sand Point Way, N.E., Seattle, WA 98115.

[89] Taylor, B. L., S. L. Mesnick, and A. E. Dizon. 1998. Progress report and suggested future research on using genetic data to define sperm whale stock structure in the North Pacific. Unpubl. doc. SC/50/CAWS19 submitted to Rep. Int. Whal. Comm.

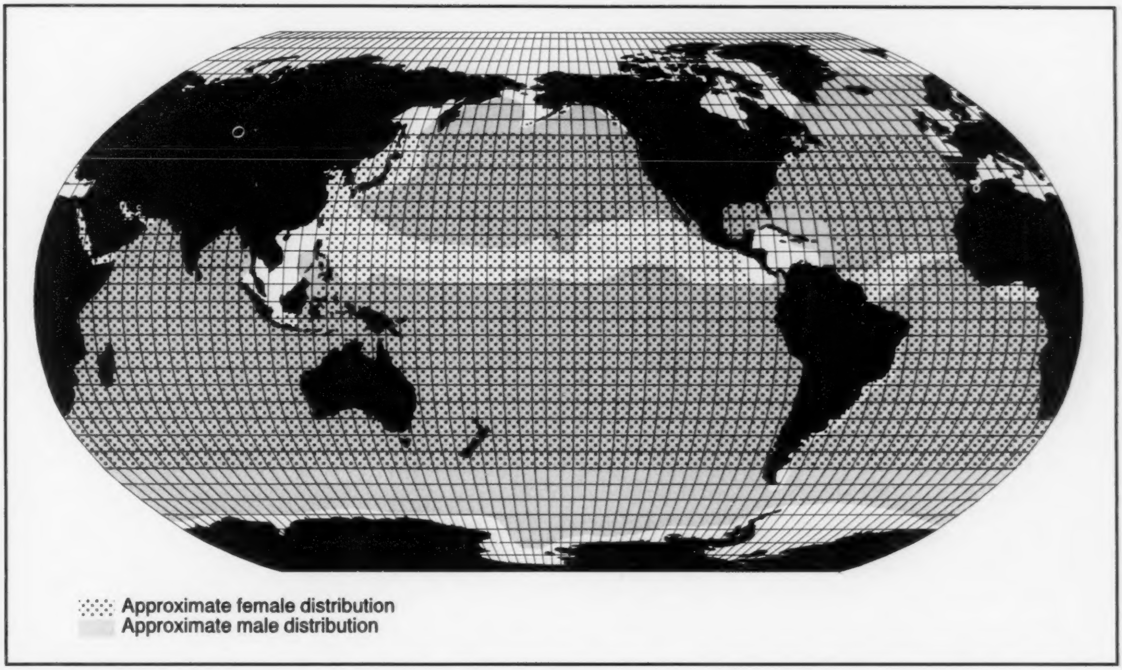


Figure 35.—Worldwide sperm whale distribution by gender. Adapted from Gosho et al. (1984).

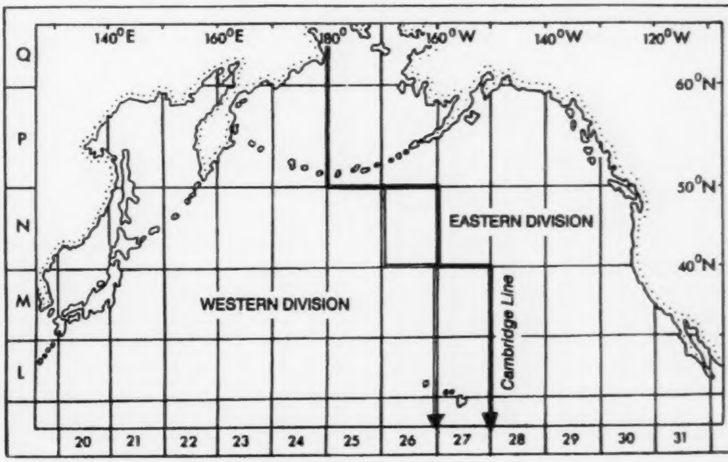


Figure 36.—The "Cambridge Line"; North Pacific sperm whale stock boundary recognized by the IWC (Donovan, 1991).

Female and immature animals stay in Atlantic temperate or tropical waters year round. In the western North Atlantic, concentrations of female/immature groups are found in the Caribbean Sea (Gosho et al., 1984) and south of New England in continental-slope and deep-ocean waters along the eastern United States (Blaylock et al., 1995). In eastern Atlantic waters, female/immature groups aggregate in waters off the Azores, Madeira, Canary, and Cape Verde Islands (Fig. 7) (Tomilin, 1967). Mature male sperm whales have been recorded as far north as Spitsbergen (Fig. 18) (Øien, 1990). All recent sightings and strandings from the eastern North Atlantic suggest a predominance of solitary and paired mature male sperm whales in waters off Iceland, the Faroe Islands, and the Norwegian Sea (Gunnlaugsson and Sigurjónsson, 1990; Øien,1990; Christensen et al., 1992a). Nine southern cephalopod species (known only from south of lat. 45°N) have been found in stomachs of male sperm whales killed off the coast of Iceland (Martin and Clarke, 1986). This suggests that these male whales are feeding in low latitudes of the North Atlantic before traveling to high latitudes. In the western North Atlantic, the Scotian Shelf's Gully and Shortland Canyon regions are frequented by male sperm whales during

summer (Whitehead et al., 1992; Mullins et al.[90]).

Schmidly (1981), Fritts[91], and Hansen et al.[92] suggested that there is a distinct stock of sperm whales in the northern Gulf of Mexico. The NMFS recognizes these Gulf of Mexico sperm whales as one distinct stock (Waring et al., 1998). However, these whales are currently recognized as part of the entire North Atlantic stock by the IWC (IWC, 1980c).

In U.S. waters of the Atlantic Ocean, sperm whales occur over the continental shelf edge (CeTAP[70]) and well into the continental slope and mid ocean regions during all seasons (Waring et al., 1998). The NMFS has recognized these western North Atlantic whales as one stock (Waring et al., 1998). There is seasonal variability in the latitudinal distribution of sperm whale concentrations in this area. In winter, concentrations exist east and northeast of Cape Hatteras (Fig. 6), and as spring approaches, these concentrations shift northward to waters off Delaware, Maryland, and Virginia, across the central portion of the Mid Atlantic Bight, and into southern Georges Bank. Throughout summer these concentrations are distributed as in the spring, but also include areas east and north of Georges Bank, the Northeast Channel, and the continental shelf south of New England. In fall, the highest concentrations occur over the continental shelf south of New England with some groups found in the Mid Atlantic Bight (Winn et al., 1987; Waring et al., 1998). Waring et al. (1993) reported significantly more sperm whales in areas where warm core rings of the Gulf Stream interact with continental shelf-edge bathymetric features than where either the warm core ring or the shelf-edge exists alone. This suggests that the interaction of variables such as sea surface temperature (SST), bottom topography, and associated primary productivity are all important to sperm whale distribution in the Atlantic Ocean.

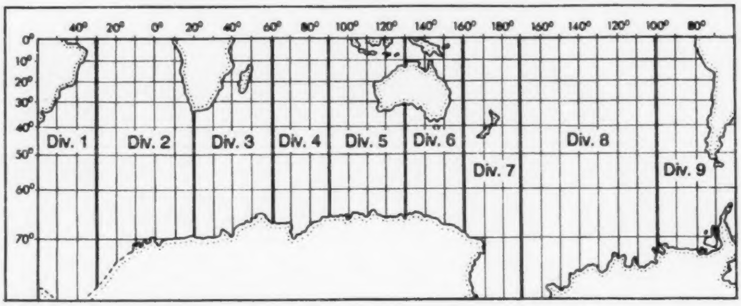


Figure 37.—IWC Southern Hemisphere stock "Division" designations for sperm whales (Donovan, 1991).

Northern Indian Ocean

There is no biological evidence to suggest genetic interchange between sperm whales in the northern Indian Ocean and sperm whales south of the Equator. This has led the IWC's Scientific Committee to assign separate stock identity to Northern and Southern Hemisphere populations in the Indian Ocean (IWC, 1995b). Little is known of the northern Indian Ocean sperm whale; however, distinct concentrations of whales have been documented off the coast of Somalia and in Sri Lanka's Gulf of Mannar (Fig. 12, 14) (James and Soundararajan, 1979; Gordon, 1991; Eyre, 1995). These concentrations are usually females and immature whales, male sightings being rare in the northern Indian Ocean (Gordon, 1991). Stranding reports are uncommon along the Indian coast for all whale species; the five sperm whale strandings reported between 1748 and 1980, were all males (James and Soundararajan, 1979).

Southern Hemisphere

For the purposes of worldwide population assessment and management, the IWC recognizes the area south of the Equator as one biogeographical region, the Southern Hemisphere. The Commission has divided this circumpolar region into nine sperm whale "Divisions" (Fig. 37). Donovan (1991) noted that these divisions are based more on manipulating available data from commercial whaling than on actual biological information. They are:

Division 1	Western Atlantic (long. 60°W–30°W),
Division 2	Eastern Atlantic (long. 30°W–20°E),
Division 3	Western Indian (long. 20°E–60°E),
Division 4	Central Indian (long. 60°E–90°E),
Division 5	Eastern Indian (long. 90°E–130°E),
Division 6	Eastern Australia (long. 130°E–160°E),
Division 7	New Zealand (long. 160°E–170°W),
Division 8	Central Pacific (long. 170°W–100°W), and
Division 9	Eastern Pacific (long. 100°W–60°W).

Male sperm whales are widely dispersed along the Antarctic ice edge from December to March (austral summer) (Gosho et al., 1984). In contrast, mixed groups of females and immature whales have a southern limit in the South Atlantic of lat. 50–54°S (Gosho et al., 1984; Tynan, 1998).

The Indian Ocean Sanctuary was created in 1979, under Article v(1)(c) of the ICRW, and all commercial whaling was prohibited within its boundaries. This boundary extends from the Antarctic continent to lat. 55°S and from long. 20°E to long. 130°E. In the western In-

[90] Mullins, J., H. Whitehead, and L. S. Weilgart. In press. Behaviour and vocalizations of two single sperm whales, *Physeter macrocephalus*, off Nova Scotia, 15 p. Can. J. Fish. Aquat. Sci.

[91] Fritts, T. H. 1983. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. Rep. prep. for U.S. Dep. Inter., FWS/OBS-82/65, 455 p.

[92] Hansen, L. J., K. D. Mullin, and C. L. Roden. 1995. Estimates of cetacean abundance in the northern Gulf of Mexico from vessel surveys. Contrib. MIA-94/95-25, NMFS Southeast Fisheries Science Center, Miami, Fla., 9 p.

dian Ocean (Division 3), there is evidence that concentrations of mixed female/immature whale groups exist south of the Seychelles (Fig. 12) (James and Soundararajan, 1979; Kasuya and Wada, 1991; Kahn et al., 1993; Eyre, 1995). In the central Indian Ocean (Division 4), concentrations of sperm whales have been recorded to the north of St. Paul and Amsterdam Islands in the austral summer (Fig. 14) (Gosho et al., 1984).

Rice (1977b), Wade and Gerrodette (1993), and Dufault and Whitehead (1995) suggested that a separate equatorial Pacific sperm whale population exists. Photo-identification studies off the Galapagos Islands and mainland Ecuador and North Peru indicate that there may also be a geographical separation between Galapagos and Ecuador/North Peru whales, although their genetic discreteness has yet to be verified (Fig. 13) (Dufault and Whitehead, 1995).

Table 17.—Recent abundance estimates for North Atlantic sperm whales.

Area	Population estimate	Coefficient of variation	Source[1]
Western North Atlantic			
U.S. EEZ[2] (1991)	337	0.50	Blaylock et al., 1995
Summer 1995	2,698	0.67	Waring et al., 1998
Spring and summer 1982	219	0.36	CeTAP[70]
Northern Gulf of Mexico			
Spring and summer 1991–94	530	0.31	Hansen et al.[92]
Eastern North Atlantic			
Iceland	1,234	0.17	Gunnlaugsson and Sigurjonsson, 1990
Faroe Islands	308	0.38	Gunnlaugsson and Sigurjonsson, 1990
Norwegian Sea	5,231	0.31	Christensen et al., 1992a
Northern Norway to Spitsbergen	2,548	0.27	Øien, 1990

[1] Source footnote numbers refer to text footnote numbers.

[2] U.S. EEZ = United States Exclusive Economic Zone (200 n.mi from nearest land).

Current and Historical Abundance

North Pacific

All current abundance estimates for the number of sperm whales in the entire North Pacific are considered unreliable. As a result, caution should be used when interpreting published estimates. Rice (1989) estimated 930,000 (no CV) sperm whales in the North Pacific Ocean. Gosho et al. (1984) estimated a total North Pacific population of 472,100 (no CV). Both of these estimates are statistically unreliable because they are based primarily on CPUE[22] data collected during whaling operations and do not take into account any possible decline in abundance that occurred after whaling ceased (IWC, 1988).

Barlow (1994a) provided a current sperm whale abundance estimate for U.S. waters off central California of 756 individuals (CV = 0.49, 95% C.I. 303–1,886). Limited trend data from 1979 to 1991 showed a relatively stable abundance of sperm whales in California coastal waters (Barlow, 1994b). Preliminary results from the winter of 1997 SWAPS survey indicated that the estimate of 756 whales may have actually been an overestimate (Taylor[88]). Using line transect data from 1991 to 1993 and 1996 ship-based surveys off California, Oregon, and Washington, Barlow[74] estimated a weighted average of 1,191 (CV = 0.22) and a minimum population estimate (N_{min}) of 995 sperm whales for those years.

From a ship-based line transect survey in the eastern tropical Pacific between lat. 10°N and 10°S, Wade and Gerrodette (1993) provided a sperm whale abundance estimate of 22,700 (CV = 0.22, 95% C.I. 14,800–34,600); although, as noted earlier, this estimate of abundance may include animals from more than one stock. No current abundance estimates are available for the entire western North Pacific.

Historical abundance estimates for the western and eastern North Pacific stocks are provided in Table 4. An abundance estimate of 620,400 animals was calculated for the entire North Pacific in 1910 (Gosho et al., 1984), although this estimate is no longer considered reliable by the IWC Scientific Committee.

North Atlantic

Based on historical whaling records and CPUE[22] data from modern whaling operations, there are an estimated 190,000 (no CV) sperm whales inhabiting the entire North Atlantic (Odell, 1992). However, this estimate is considered unreliable by the IWC's Scientific Commitee (IWC, 1988).

Recent regional abundance estimates have been calculated for both the western and eastern North Atlantic (Table 17). These numbers, from ship-based and aerial surveys conducted over several seasons, are much smaller than those summarized by Gosho et al. (1984). The small sample sizes, limited coverage, and probable undercounting of whales in the areas result in statistical biases within these estimates (Barlow and Sexton[93]).

Historical abundance estimates for Icelandic, Azorean, and Spanish North Atlantic stocks are provided in Table 4. An initial abundance estimate of 224,800 animals was calculated for all North Atlantic stocks in 1905 (Gosho et al., 1984), although this estimate is no longer considered reliable by the IWC Scientific Committee.

Northern Indian Ocean

There are no current population abundance estimates available for the northern half of the Indian Ocean.

Southern Hemisphere

The current estimate of 299,400 (no CV) sperm whales from the Equator to lat. 70°S dates from 1977 and is statistically unreliable (IWC, 1988). This estimate was calculated on the basis of historical whaling records and CPUE[22] data from whaling operations (Odell, 1992).

Utilizing JSV and IWC/IDCR survey data, Butterworth et al.[47] estimated sperm whale abundances south of lat. 60°S (3,200–14,000; CV = 0.39–0.19) and south of lat. 30°S (128,000–290,000;

[93] Barlow, J., and S. Sexton. 1996. The effect of diving and searching behavior on the probability of detecting track-line groups, g_0, of long-diving whales during line-transect surveys. NMFS Southwest Fisheries Science Center, La Jolla, Calif., Admin Rep. LJ-96-14.

CV = 0.44–0.46), respectively (Table 18). Given the Antarctic latitudes surveyed, these numbers most likely represent a large proportion of male whales.

In South Pacific waters, Childerhouse et al. (1995) determined, using photo-identification and an "open" mark-recapture model, that between 60 and 180 (no CV) male sperm whales occur off Kaikoura, New Zealand (Division 7), each winter. In the equatorial Pacific, the total population of sperm whales between the Galapagos and Ecuador and North Peru was estimated at 3,891 (95% C.I. 2,600–5,300) (Whitehead et al., 1992).

Historical abundance estimates for the nine Southern Hemisphere divisions are provided in Table 19. An abundance estimate for the year 1946 of 547,600 sperm whales (no CV) for the entire Southern Hemisphere was calculated from these division-based estimates. All of these estimates are statistically unreliable due to their use of historical whaling catch data and CPUE[22] from whaling operations. It is important to note that sperm whale catches from the early 19th century through the early 20th century were calculated on barrels of oil produced per whale rather than the actual number of whales caught. Extrapolation from these types of data has led to only rough estimates of the number of whales killed per year (Gosho et al., 1984). In addition, newly revealed Soviet whaling catch data from Southern Hemisphere factory ships indicate considerable underreporting of sperm whale catches (Zemsky et al., 1995; Zemsky et al., 1996). According to these "new" catch data, approximately 14,700 harvested sperm whales went unreported in the original Soviet catch data between 1947 and 1987. As more of these Soviet data are made available, catch-based population estimates will need to be revised.

Table 18.—Ship-based line transect abundance estimates of Antarctic circumpolar sperm whales (Butterworth et al., text footnote 47).

Area by year	Population estimates	CV
South of lat. 60°S		
1978/79–1983/84	3,200	0.39
1985/86–1990/91	14,000	0.19
South of lat. 30°S		
1965/66–1977/78	290,000[1]	0.46
1978/79–1987/88	128,000[1]	0.44

[1] Extrapolated from Japanese Survey Vessel (JSV) data (Jan.–Feb. only).

Table 19.—Estimated historical abundance of sperm whales in the Southern Hemisphere for the year 1946 (Gosho et al., 1984) based on 1978 and 1980 IWC catch data.

IWC stock division	Population estimate
1	32,700
2	72,100
3	80,700
4	49,700
5	49,600
6	29,800
7	42,000
8	96,200
9	94,800
Total	547,600

Historic Exploitation Patterns

North Pacific

Large-scale pelagic whaling in the North Pacific Ocean ceased in 1980, but U.S. fleets found few whales and therefore had stopped whaling by 1979 (Tønnessen and Johnsen, 1982). In 1988, the IWC banned the killing of sperm whales. Table 20 summarizes current estimates of sperm whale catches from the North Pacific stocks by whaling operations from 1911 to 1987[94]. It must be noted that these numbers, especially those from Japanese whaling operations, may lead to underestimation of historic abundance due to underreporting to the IWC (Kasuya and Miyashita, 1988). The total estimated post World War II take from the entire North Pacific is 258,000 animals. Not specifically indicated in Table 20, but of significance to North Pacific stocks, are the number of whales (mostly males) taken from the Bering Sea (Fig. 38). Although there were no estimates of whales caught in this region, a significant decline in CPUE[22] north of lat. 50°N led Kasuya (1991) to conclude that the Bering Sea sperm whale population had been greatly depleted.

[94] Based on barrels of oil produced per whale.

North Atlantic

In the North Atlantic, the hunting of sperm whales occurred off the west coast of Iceland, Norway (coastal and pelagic), the Faeroe Islands, Britain (coastal), West Greenland, Nova Scotia, Newfoundland/Labrador, New England, the Azores, Madeira, Spain, and Spanish Morocco (Waring et al., 1998) (Fig. 6, 7). Some whales were taken off the U.S. Mid Atlantic coast, although the number of whales actually caught is unclear in the literature (Townsend, 1935; Reeves and Mitchell, 1988). Commercial whaling operations for sperm whales were also conducted in the northern Gulf of Mexico during the late 1700's to the early 1900's (Townsend, 1935). There are no catch estimates available for the number of sperm whales caught during the U.S. operations. The numbers caught in Norway and off Canada are summarized in Table 20.

Southern Hemisphere

The average annual catch of sperm whales in the Southern Hemisphere from 1956 to 1976 was over 20,000 whales. Gosho et al. (1984) provided summaries of those and worldwide sperm whale catch levels.

Current Exploitation

IWC worldwide catch limits (quotas) for all sperm whale stocks are currently set at zero (IWC, 1995b). As a result of

Table 20.—Recorded sperm whale catch numbers from North Pacific and North Atlantic whaling operations.

Area	Years	No. of animals	Source
North Pacific			
Western North Pacific (Kurils, Hokkaido, Sanriku, central & south Japan)	1911–45	19,989	Kasuya, 1991
Eastern North Pacific	pre-WWII	3,699	Kasuya, 1991
Total from Japanese operations	1955–86	62,033	Kasuya and Miyashita, 1988
Total North Pacific	1947–87	258,000	Barlow et al., 1995b
North Atlantic			
Western Norway	1925–69	374	Christensen et al., 1992a
Western Norway	1948–71	1,088	Christensen et al., 1992a
Newfoundland/Labrador	1904–72	424	Blaylock et al., 1995
Nova Scotia	1964–72	109	Blaylock et al., 1995

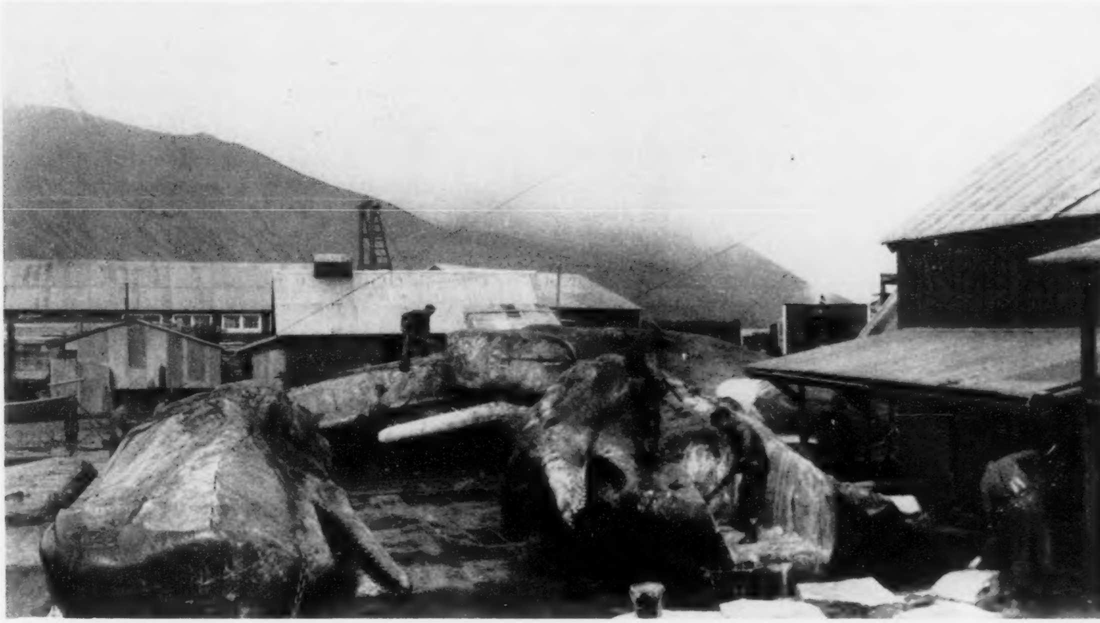


Figure 38.—Three sperm whales on a flensing platform in Alaska. The right animal's spermaceti organ has been removed. University of Washington Special Collections, Lagen Collection, negative UW17505.

this prohibition on whaling, the number of reported sperm whale kills for either commercial or aboriginal harvest has been zero in recent years (IWC, 1995a). The only known subsistence harvest of sperm whales occurs in Lomlem, Indonesia, where a few whales are taken per year using primitive methods (Barnes, 1991). Today the threat of commercial overharvest is greatly reduced compared to the potentially more long-term threats of habitat degradation, marine pollution, human exploitation of potential prey, and commercial fisheries interactions.

Life History and Ecology

Feeding

In general, the sperm whale's primary prey consists of larger mesopelagic cephalopod and fish species, including the giant squid, *Architeuthis* sp. Approximately 40 species of cephalopods are consumed by sperm whales worldwide. In the North Pacific, the four most common prey items of sperm whales off central California are all cephalopod species (i.e. *Moroteuthis*, *Gonatopsis*, *Histioteuthis*, and *Galiteuthis*) (Fiscus et al., 1989). In the Indian Ocean, the cephalopod species most commonly eaten by sperm whales are of the Histioteuthid family (Gordon, 1991). Sperm

Figure 39.—Showing its square-shaped head, a sperm whale breaches in the distance. S. Leatherwood, NMML Collection.

whales in the high latitudes of the North Atlantic (i.e. Norwegian Sea and Iceland) feed on deep-dwelling fish species of the genus *Cyclopterus* (lumpsuckers) and *Sebastes* (redfishes). Fish prey comprises almost half of the total biomass eaten by sperm whales in this region, while the other half is comprised of cephalopods (Martin and Clarke, 1986; Christensen et al., 1992b).

Reproduction

One of the most recognizable features of sperm whale social structure is the "nursery school" that contains between 20 and 30 individuals, including females, calves, and juveniles (Whitehead and Arnbom, 1987; Whitehead, 1996; Richard et al., 1996). At around 6 years of age, juvenile males (and possibly females) leave these nursery schools to form juvenile or bachelor schools (Richard et al., 1996). Juvenile schools contain individuals between 4 and 20 years of age and are less cohesive and smaller than the nursery schools (Whitehead and Arnbom, 1987). By the time males reach 30 years of age, they are mostly solitary.

Breeding among sperm whales takes place in spring and early summer in both hemispheres (from April to August in the Northern Hemisphere and from October to February in the Southern Hemisphere). Pairings take place in the lower latitudes, where males join nursery schools for days at a time. However, photo-identification studies suggest that not all males breed each year (Martin, 1980; Whitehead and Arnbom, 1987).

Females reach sexual maturity at 9 years of age and a length of approximately 9 m. The calving interval is one of the longest for mammals, between 4.8 and 6 years (Kasuya, 1991). Gestation lasts from 14 to 16 months, and lactation is between 1 and 2 years (Kasuya, 1991). Males reach sexual maturity at 20 years of age and a length of 12 m. At around 30 years of age, males reach "social" maturity and begin living the previously mentioned solitary life.

Pregnancy rates vary between exploited and unexploited stocks. Exploitation of sperm whale stocks may have caused a density-dependent response, which increased the average pregnancy rate of 20% in unexploited populations to 25% in exploited populations (IWC, 1980c).

Natural Mortality

Serological studies on North Pacific and North Atlantic sperm whales indicate that these whales are carriers of and are infected by calciviruses and papillomavirus (Smith and Latham, 1978; Lambertsen et al., 1987). For example, there was evidence of papillomavirus-associated disease in 10% of a population sample taken from Iceland (Lambertsen et al., 1987).

Killer whales, false killer whales, *Pseudorca crassidens;* and short-finned pilot whales, *Globicephala melana,* have all been observed in what appears to be harassment of sperm whale groups (Arnbom et al., 1987; Palacios and Mate, 1996; Weller et al., 1996). Sperm whale defensive maneuvers in these interactions seem to be based on protection of the youngest and most vulnerable of the group (Nishiwaki, 1962; Weller et al., 1996). Bleeding wounds have been observed on sperm whale heads and tail flukes after such events (Arnbom et al., 1987; Dufault and Whitehead, 1995). The most recent documented incident of killer whales attacking sperm whales occurred off Point Conception, Calif., in October 1997 (Roberts[95]). During the attack, approximately 25 killer whales mortally wounded at least one of nine sperm whales. The incident was unusual because it apparently involved only large, mature sperm whales. The attacked whales showed no defensive actions except in protecting injured members of their pod.

Estimated natural mortality rates for sperm whales are age-specific. Juveniles (age 0–2) have an estimated annual mortality of 0.09, while mature (age 2 and above) whales have an estimated annual mortality of 0.05 (IWC, 1971). Because of the lack of information on the causes of natural mortality in sperm whales, these rates are no longer considered statistically reliable by the IWC (IWC, 1980c).

[95] Roberts, K. 1998. NOAA Corps Officer, Pacific Marine Environmental Laboratory-EDD, 7600 Sand Point Way, N.E., Seattle, WA 98115. Personal commun.

Human-related Mortality

Fisheries Interactions

In U.S. waters of the Pacific, incidental take of sperm whales has been documented in drift gillnet operations. The average annual rate of mortality and serious injury from the offshore California drift gillnet fishery from 1991 to 1995 is nine sperm whales (Barlow et al., 1997). Observers aboard Alaska sablefish, *Anoplopoma fimbria*; and Pacific halibut, *Hippoglossus stenolepis*, longline vessels have documented sperm whales feeding on longline-caught fish in the Gulf of Alaska (Hill and Mitchell[96]). In 1997, the first entanglement of a sperm whale in Alaska's longline fishery was recorded, although the whale was not seriously injured (Hill and DeMaster[97]). There is no evidence that mortality or serious injury occurs as a result of interactions with this fishery; however, the nature and extent of these longline fishery-sperm whale interactions is not yet clear.

The first observed incidental take of a sperm whale in U.S. waters of the North Atlantic was in 1989 in a drift gillnet. The estimated fishery-related mortality and serious injury rate was 2.2 sperm whales in 1989, 4.4 in 1990, and zero from 1991 to 1996 (Waring et al., 1998), although in 1995 one sperm whale was observed entangled in a pelagic drift gillnet. This entangled whale was released alive, although gear remained wrapped around several body parts. Waring et al. (1998) describe three known instances of sperm whale entanglements in the northwest Atlantic; two in net gear and one in longline gear.

There is little information available regarding fishery interactions with sperm whales outside U.S. waters. However, behavior similar to that observed in the Alaska longline fishery has also been documented during longline operations off South America (South Georgia, Kerguelen, and southern

[96] Hill, P. S., and E. Mitchell. 1998. Sperm whale interactions with longline vessels in Alaska waters during 1997. Unpubl. rep. presented at 6th Pacific Scientific Review Group Meeting, March 30, 1998, Honolulu, Hawaii. Avail. from National Marine Mammal Laboratory, 7600 Sand Point Way, N.E., Seattle, WA 98115.

[97] Citation updated in proof: see Hill and DeMaster, 1999 in literature cited.

Table 21.—Factors possibly influencing the recovery of sperm whale stocks under the ESA (1973) §4(a)(1)1992 Amend.

Factor	North Pacific	North Atlantic	Gulf of Mexico	Indian Ocean	Southern Hemisphere
1. Present or threatened destruction or modification of habitat	Pollution	Pollution (e.g. plastics, heavy metals)	Oil and gas development (e.g. noise disturbance, oil spills)	Pollution	Pollution
2. Overutilization for commercial, recreational, scientific, or educational purposes	Unknown	Whale watching and associated vessel traffic	Scientific research and associated vessel traffic	Unknown	Whale watching, scientific research, photography, and associated vessel traffic
3. Disease or predation	Papilloma and calcivirus; *Orcinus* attacks	Papilloma and calcivirus	Papilloma and calcivirus; *Orcinus*, *Pseudorca*, and *Globicephala* attacks	Papilloma and calcivirus	*Orcinus* and *Pseudorca* attacks
4. Other natural or man-made factors	Entanglement in fishing gear (e.g. longline, drift gillnets)	Entanglement in fishing gear (e.g. drift gillnets)	Unknown	Unknown	Entanglement in fishing gear (e.g. longline)

Chile) where sperm whales have become entangled in longline gear, have been observed feeding on fish caught in the gear, and have been reported following longline vessels for days (CCAMLR, 1994; Ashford et al., 1996; Capdeville, 1997). These observations, combined with anecdotal reports suggest that interactions between sperm whales and longline operations may be widespread in the waters off South America (Hill and Mitchell[96]).

Noise Disturbance

In recent years, many studies on the effect of noise on the behavior of whales have been done (Richardson et al., 1995). A resident population of sperm whales occurs in the northern Gulf of Mexico, an area of intensive oil and gas exploration and development activities. Oil production platforms and their associated vessels have unknown effects on sperm whales (Odell, 1992). Studies of whale reactions to seismic surveys in the Gulf of Mexico indicated that sperm whales reacted to seismic pulses by moving away 50 km or more (Mate et al., 1994). In the southern Indian Ocean, most sperm whales stopped vocalizing when exposed to seismic pulses as much as 300 km away (Bowles et al., 1994). Sperm whales have also been observed exhibiting startle responses to a closely approaching vessel (Whitehead et al., 1990). Observed reactions of sperm whales in the presence of vessels include more erratic surface movements, reduced surface time, fewer blows per surfacing, shorter intervals between successive blows, and increased frequency of dives without raised flukes (Cawthorn, 1992; Gordon et al., 1992). It is unknown whether anthropogenic noise has biological significance for sperm whales.

Pollution

Relatively high mercury levels have been found in breeding females captured off southern Australia. It is unclear whether these mercury levels affect the whale's health (Cannella and Kitchener, 1992). Plastic debris is probably ingested quite frequently by sperm whales at sea. For example, a 15 m male sperm whale captured in nearshore waters off Iceland had a 3-gal plastic bucket lodged in his intestinal tract (Lambertsen and Kohn, 1987).

Classification Status

The sperm whale was listed as endangered under the ESA in 1973 and is protected under the MMPA. Endangered status is applied to all sperm whale stocks utilizing U.S. waters (Anonymous, 1994b). The western North Pacific stock is the only sperm whale stock designated as a "Protected Stock" by the IWC. Under this designation, the IWC recognizes that these whales are 10% or more below their maximum sustainable yield (MSY) level, or 54% of carrying capacity (K) (IWC, 1995b). Although without trend data or information on status relative to K for this stock, the validity of this designation is questionable.

Since Braham's 1991 status review[3], there has been little new information to improve the accuracy of population estimates or stock identity. One of the major difficulties in identifying distinct sperm whale stocks is their heterogenous and widespread distribution, which is apparently gender- and age-related. Table 21 summarizes information on potential threats affecting the status of sperm whales. Therefore, any reevaluation of sperm whale classification status awaits the collection of more reliable information on distribution, migration patterns, abundance, and trends in abundance on a stock-specific basis, as well as the development of objective delisting criteria. Nonetheless, if the accuracy of abundance estimates and stock determinations for North Atlantic and North Pacific sperm whale populations can be made more reliable with additional survey data, and if human-related sources of mortality and serious injury remain low, some stocks might be candidates for downlisting.

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